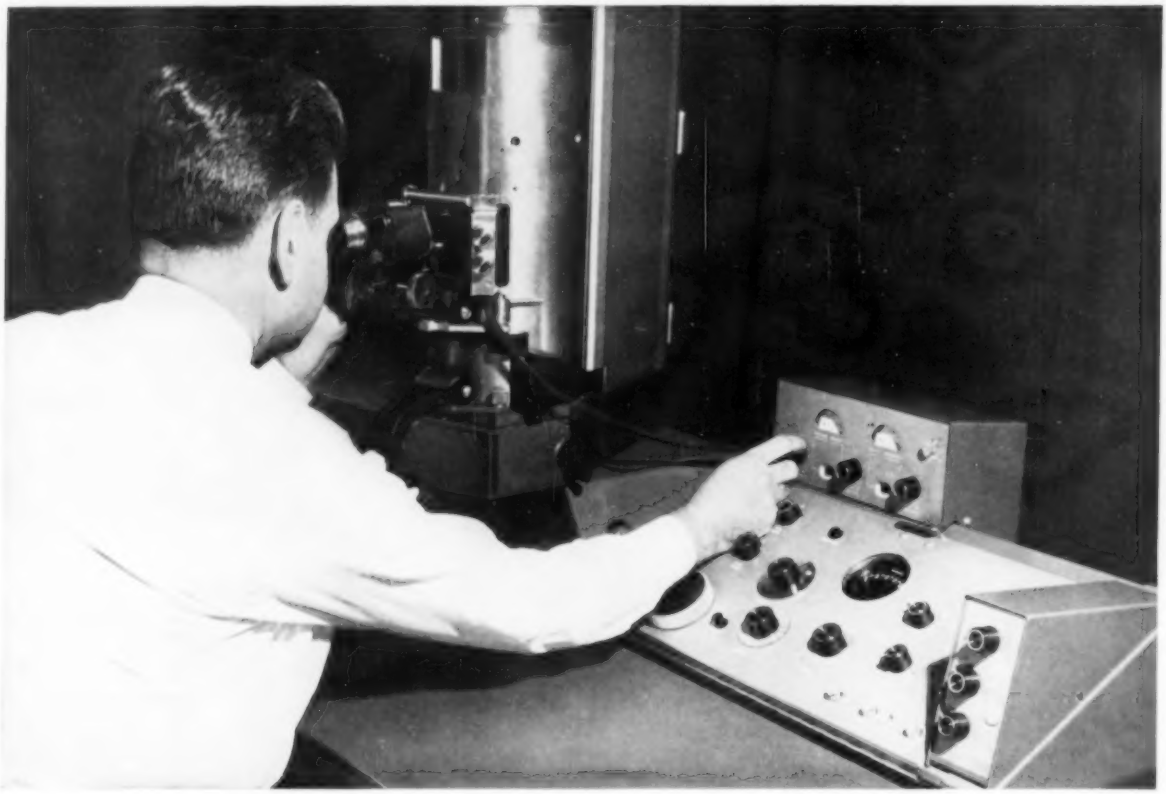
JOURNAL OF

METALS

APRIL 1959

MASTERING THE MOLECULE...WITH ELECTRON MICROSCOPY



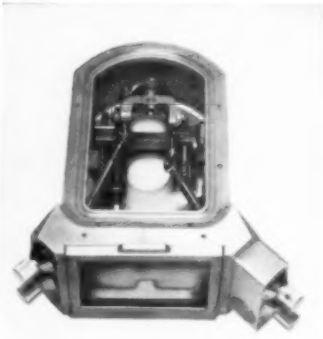
New Electron Diffraction Chamber increases versatility of RCA Electron Microscopes

Now the usefulness of RCA Electron Microscopes in the metallurgical and chemical fields has been further extended by a Diffraction Chamber which permits EMU microscopes to do both reflection and transmission electron diffraction. Typical applications of the Diffraction Chamber are: the study of phase changes in metallic surfaces as temperature is raised, chemical micro-analysis, the investigating of contaminants of catalysts, and the causes of bonding or adhesion failures. Temperature of specimens can be raised to 900° C.

The use of a transistor for electronic reduction of ripple in the heater marks the first time these devices have been applied to electron microscopes.

Major features which have made the RCA Electron Microscope the most widely used instrument of its kind in the world include: direct magnifications to 200,000X; complete versatility in photographic work; high speed vacuum system; radio frequency type power supply; and unusual convenience of operation, giving more time for evaluation of results.

RCA also offers the world's most versatile X-ray diffraction instruments, renowned for their technical excellence and operating simplicity. And, an important plus when you purchase RCA equipment is the availability of installation supervision and contract service by the RCA Service Company to keep your instrument operating at its peak.



Stage assembly of Electron Diffraction chamber for EMU-3 Electron Microscopes.

For illustrated literature on the RCA Electron Microscope or X-ray Diffraction instruments, write to RCA, Dept. S-347, Building 15-1, Camden, N.J. In Canada: RCA VICTOR Company Limited, Montreal.

RADIO CORPORATION of AMERICA

CAMDEN, N. J.

Trade(s) ®

JOURNAL OF

METALS

Vol. 11, No.4
April, 1959

reporter 221
education 227
personnel 208
editorial 237
April Transactions Contents 240
aime news 287
coming events 294
advertisers index 294

Know Your Society 241
National Open Hearth Steel Program 244
Blast Furnace, Coke Oven, and Raw Materials Program 246
Blast Furnace, Coke Oven, and Raw Materials Committee 248
National Open Hearth Steel Committee 249
National Open Hearth Steel—Local Section Activities 250

COVER:

There is something dramatic about a blast-furnace cast, so found our cover artist, David Cain, while touring the Lackawanna plant of Bethlehem Steel Co. Within the covers, open-hearth history, LD today, and a new direct-reduction technique are features of special interest to iron and steel makers.

Cold Iron 255
Poem by Kipling, Photograph by Cain

LD Operations at Aliquippa 256
by D. R. Loughrey

Steelmaking/USA 261
by Leo F. Reinartz

Electric Direct-Reduction Process 265
by Albert de Sy

Zinc Blast-Furnace Operation 270
by S. W. K. Morgan and J. Lumsden

Dispersion Strengthened Alloys, Part II 276
by Claus G. Goetzel

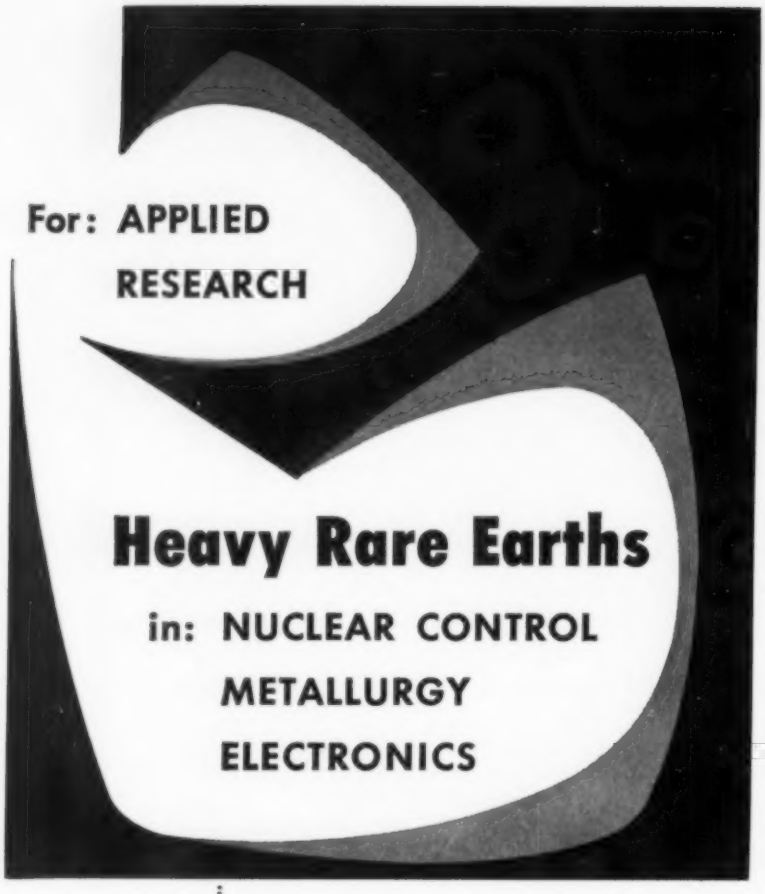
Enhanced Diffusion Conference 281
by G. J. Dienes

The 1959 Annual Meeting 282
A Staff-Written Summary

EDITORIAL STAFF: Editorial Director, Rixford A. Beals; **Managing Editor,** F. Weston Starratt; **Associate Editor,** James J. Burke; **Production Editor,** Otto Johnson; **News Editor,** J. B. Van Cronkhite; **Editorial Assistant,** C. M. Cardon.

ADVERTISING STAFF: Advertising Service Mgr., Grace Pugsley; **Assistant Service Mgr.,** W. J. Sewing; **Advertising Representative:** The McCarty Company, 122 East 42nd St., New York 17, N. Y.; **Eastern Advertising Manager,** Thomas G. Orme, 29 West 39th St., New York 18, N. Y.; **Southeastern Advertising Representative,** Fred W. Smith & Associates, 1201 Forest View Lane, Vesthaven Birmingham, Ala.; **Western Advertising Representative,** Dillenbeck-Galavan Inc.; 266 S. Alexandria Ave., Los Angeles 4, Calif.

Address insertion orders and copy to: Advertising Department, JOURNAL OF METALS, 29 West 39th Street, New York 18, N. Y. Send plates to: JOURNAL OF METALS, C/O Lew A. Cummings Co., Inc., 215 Canal St., Manchester, N. H. Published the first day of each month by the American Institute of Mining, Metallurgical and Petroleum Engineers, Inc., 29 West 39th Street, New York 18, N. Y. Telephone: PEnnsylvania 6-9220. Subscription $10 per year for non-AIME members in United States and North, South, and Central America; $10, foreign; $6 for AIME members, or $4 additional for members only in combination with a subscription to "Mining Engineering" or "Journal of Petroleum Technology." Single copies, $1.50., Transactions of The Metallurgical Society of AIME, $5 additional to members, $20 to non-members, and $25 foreign . . . The AIME is not responsible for any statement made or opinion expressed in its publications . . . Copyright 1959 by the American Institute of Mining, Metallurgical, and Petroleum Engineers, Inc. . . . Registered cable address, AIME New York . . . Indexed in Engineering Index, Industrial Arts Index, and Chemical Abstracts . . . Second class postage paid to New York, N. Y., and at Manchester, N. H. Numbers of copies in this issue, 10,700.



Metals and Oxides

of

NEODYMIUM

SAMARIUM

EUROPIUM

GADOLINIUM

TERBIUM

DYSPROSIUM

HOLMIUM

ERBIUM

THULIUM

YTTERBIUM

LUTETIUM

YTTRIUM

Investigate these advantages: Gadolinium has the highest thermal neutron cross-section (46,000 Barns) of any known element. Other advantages include a melting point of 1350° C. and oxide dispersion of nearly 40% in titanium and stainless steel. This suggests use in metallic, cermet, and ceramic control rods.

Yttrium metal is equally interesting with a high melting point of 1552° C. and a low density of 4.49. Its crystal structure, cph, is similar to titanium. This suggests use in alloy systems, cermets, and ceramics. The yttrium iron garnet, with its narrow, ferromagnetic, line-width-resonance, also warrants consideration in micro-wave isolators, circulators, and modulators.

Michigan Chemical can supply experimental or commercial quantities of rare earth oxides (99.9%) and rare earth metals (99%) from inventory. As process developments are making price changes possible, inquire by phone or letter for up-to-date quotations and latest technical data.

Reg. U.S. Pat. Off.

MC

©

RE-58-3

MICHIGAN CHEMICAL CORPORATION

615 North Bankson Street

Saint Louis, Michigan

PERSONNEL

► These items are listings of the Engineering Societies Personnel Service, Inc. This Service, which cooperates with the national societies of Civil, Electrical, Mechanical, Mining, Metallurgical, and Petroleum Engineers, is available to all engineers, members and non-members, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 5% of the first year's salary if a non-member, or 4% if a member. Also, that you will agree to sign our placement fee arrangement which will be mailed to you immediately, by our office, after receiving your application. In sending applications be sure to list the key and job number.

When making application for a position include eight cents in stamps for forwarding application to the employer and for returning when possible.

A weekly bulletin of engineering positions open is available at a subscription rate of $3.50 per quarter or $12 per annum for members, $4.50 per quarter or $14 per annum for non-members, payable in advance. Local officers of the Personnel Service are at 8 W. 40th St., *New York 18;* 57 Post St., *San Francisco;* 84 E. Randolph St., *Chicago 1.*

— MEN AVAILABLE —

Metallurgical Engineer, B.S., age 38. Ten years diversified experience in materials engineering and development on high-temperature and stainless materials, at project and supervisory level. Location desired, immaterial. M-209

Chemical Engineer, M.Ch.E degree, age 29. Eight years in research development and process engineering in the fields of hydrometallurgy, filtration, and heat transfer including 1½ years in supervisory research position in extractive hydrometallurgy of non-ferrous metals. Desire responsible or process engineering position. M-210.

Manager, E.Met. degree, age 42. Graduate and registered mining and metallurgical engineer, managed non-ferrous or non-metallic mining, processing or manufacturing operation with economical efficiency gained from 15 years experience; English and Spanish in management, production, research, and development. Available soon for small or medium sized, well established company. Prefer Colorado, Idaho, Montana. M-207, San Francisco.

Metallurgical Engineer, B.Sc., B.Eng., age 28. Six years varied experience, all heat operations, babbitting and white metals, field failure analysis, material selection. Prefer East. M-211.

— POSITIONS OPEN —

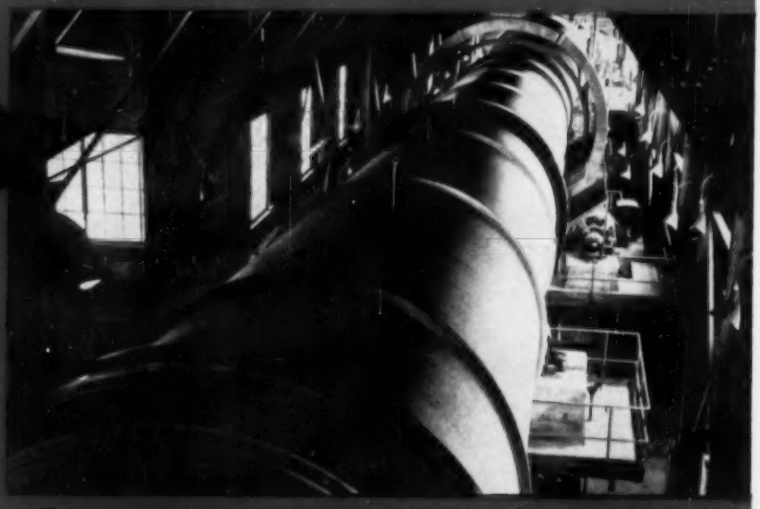
Technical Sales Engineer, graduate electrical or metallurgical engineer preferred, with a minimum of two years practical engineering experience. Should preferably have some sales training. Following a period of in-plant training, will be

(*Continued on page 210*)

SMIDTH

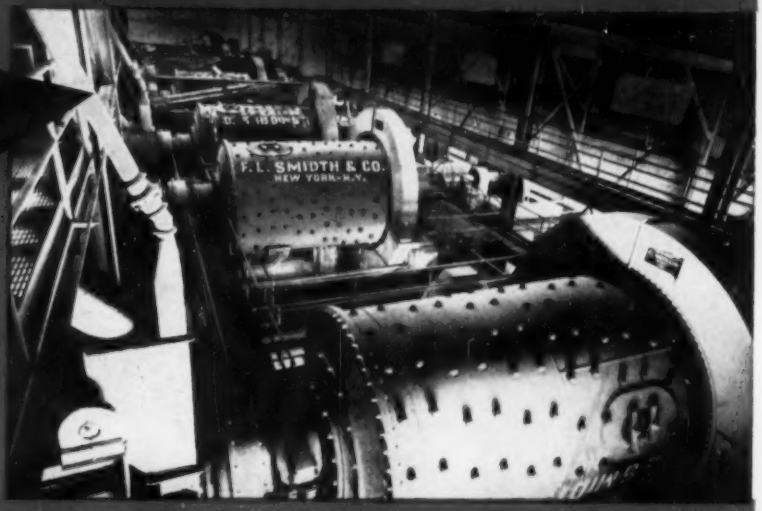
Rotary Kilns

For sintering, nodulizing, calcining, desulphurizing, oxidizing and reducing roasting—coolers, precoolers, preheaters, recuperators—and auxiliary equipment.



Grinding Mills

Ball mills, tube mills and multicompartment mills—open or closed circuit—wet or dry grinding also airswept for grinding and drying.



Over 1,000 Smidth Rotary Kilns and over 5,000 Grinding Mills supplied all over the world.

F. L. Smidth & Co.
Engineers and Machinery Manufacturers
11 West 42nd Street
New York 36, N. Y.

F. L. Smidth & Co., A/S
77 Vigerslev Alle
Copenhagen, Denmark

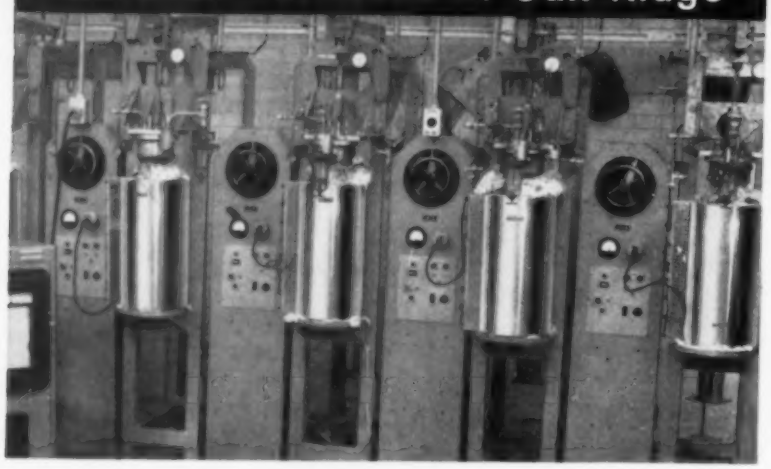
F. L. Smidth & Co., Ltd.,
105, Piccadilly,
London, W. 1, England

F. L. Smidth & Cie France
80 Rue Taitbout
Paris (9e) France

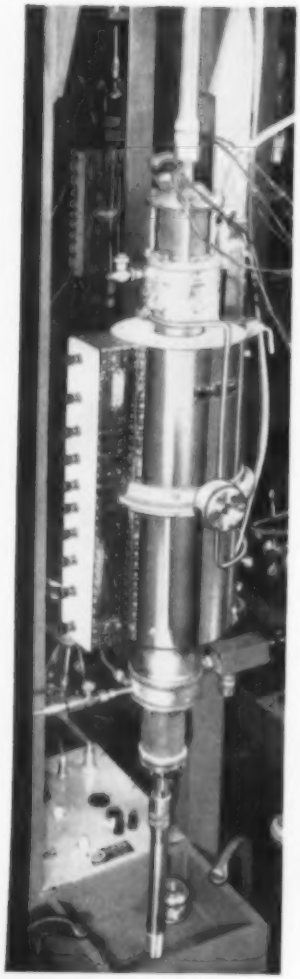
F. L Smidth & Co. of Canada, Ltd.
11 West 42nd Street
New York 36, N. Y.

F. L. Smidth & Co. (Bombay) Private Ltd.
42 Queen's Road
Bombay, India

Marshall Furnaces at Oak Ridge



1000 to 1800° F ± 1.5°



At Oak Ridge, Marshall furnaces accurately maintain set temperature levels in the range of 1000 to 1800° F., within ± 1.5° F. The furnaces are vital components of specially designed and built gaseous and vacuum creep rigs. Creep properties of structural metals are tested under the effect of high temperature gases, vacuum, various liquids, and liquid metals. The rigs were developed by the Oak Ridge National Laboratory, operated by Union Carbide Corporation for the U. S. Atomic Energy Commission, and the furnaces were built to their specifications by Marshall Products Co. After more than four years of virtually continuous service, all major components are still in operation!

This accuracy and dependability is typical of Marshall furnaces used widely as components of machines for creep testing metallic alloys, and also for tensile, stress-rupture, and fatigue testing of metals, ceramics and cermets.

Marshall offers a range of standard tubular, shunt-type furnaces compactly designed to apply electrical heat *up to 2600° F*, under exact control. Units feature *uniform temperature distribution* and *rigid zone control to ± 3° F* at any point in the test zone. Under certain conditions operators report temperatures can be held to ± 1° F. Test durations may range from moments to 10,000 or more hours.

MARSHALL PRODUCTS CO.

tubular furnaces and control panels

270 W. LANE AVENUE, COLUMBUS 2, OHIO

write today for complete information

Liquid-metal creep testing frames (shown at top)
Creep testing in various gaseous environments (left)

Personnel

(Continued from page 208)

employed in technical sales of aluminum products used as an electrical component by leading manufacturers. Salary, $8000 to 12,000 year depending on experience; excellent opportunities for advancement. Considerable travel. Must be willing to live in the East, Midwest, or South as designated by the company. Headquarters, Connecticut. W7142.

Research and Development Engineers, with Ph.D in math, nuclear physics, or metallurgy, to do applied research and development in engineering and scientific problems related to reactor design. Salaries to start upwards of $10,000 year ranging to a maximum of $13,000 year. Location, East. W7133.

Mechanical or Metallurgist for sale of extreme high-temperature refractories as used in aluminum, steel manufacture. Salary, $7500 to 8000 year. Location, northern New York State. W7129(b).

Sales Engineers. (a) Mechanical, Chemical, and Metallurgical Engineers with heavy background in sales. Some knowledge of metal powders and parts made from metal and ceramic powders desirable. Salary, $8500 to 9000 year. (b) Sales Trainees, with degrees above. Salary, $4000 to 5000 year. Excellent opportunities with rapidly growing and well established industry. Headquarters, Pennsylvania. W7096.

Extractive Metallurgist, Metallurgical Engineer for responsible position in research and development program in electric furnace smelting with young, progressive company; some furnace experience desirable. Salary open depending upon qualifications. Location, East. W7095.

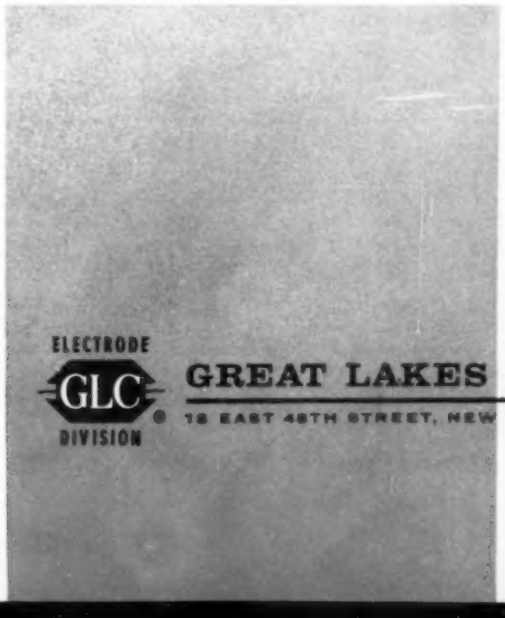
Assistant Forging Plant Superintendent, graduate mechanical, industrial, or metallurgical engineer desirable, with 10 to 15 years experience in precision forging work, preferably with high-temperature alloys and on parts used by aircraft engine manufacturers; 5 to 10 years responsibility as forging superintendent, directing die making, forging, and polishing operations. Should have general knowledge of engineering and close familiarity with manufacturing methods required to produce precision forgings; specific knowledge of forging tools and dies. Will direct forging, machining, polishing, inspection, and testing of turbine parts in accordance with engineering, cost, quality, and delivery requirements. Salary, $15,000 year plus bonus. Location, East. W7003.

(Continued on page 218)

IN THE FINAL ANALYSIS

• • • the superior quality of an electrode is a major factor in lowering the per-ton cost of electric steels.

PRODUCTS ELECTRODE GLC DIVISION YOU CAN TRUST



ELECTRODE GLC DIVISION

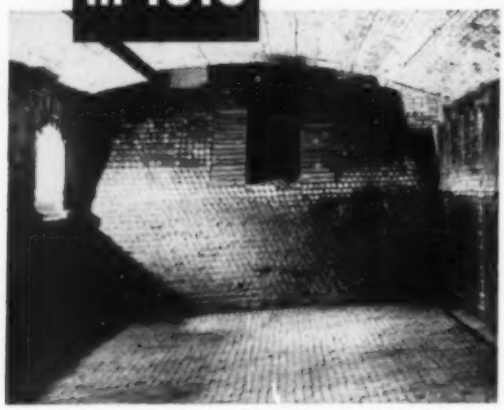
GREAT LAKES CARBON CORPORATION

18 EAST 48TH STREET, NEW YORK 17, N. Y. OFFICES IN PRINCIPAL CITIES

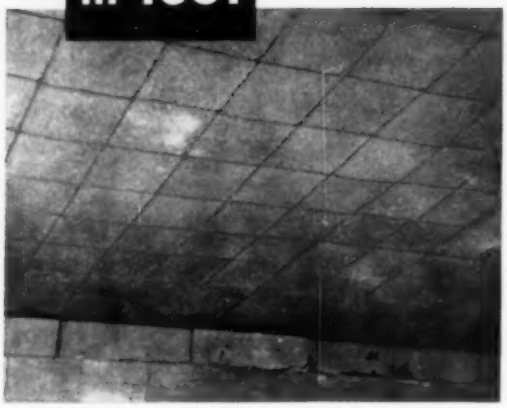
HARBISON-WALKER HISTORY OF PROGRESS IN REFRACTORIES FOR THE ALL-BASIC OPEN HEARTH FURNACE

Harbison-Walker Refractories Company from its first beginnings, in 1865, only several years short of a century ago, has closely worked with the iron and steel industries in the production of refractories needed to make possible the rapid evolutionary advances in furnace practice. This progress involves increased severity of operating conditions including much higher temperatures and larger furnaces with increased rates of production, accompanied by the use of oxygen with all its benefits. Rates of steel production based on sizes and designs of furnaces — noteworthy advances in metallurgical practice — and availability of superior refractories, in many instances, have been substantially increased.

in 1916



in 1931



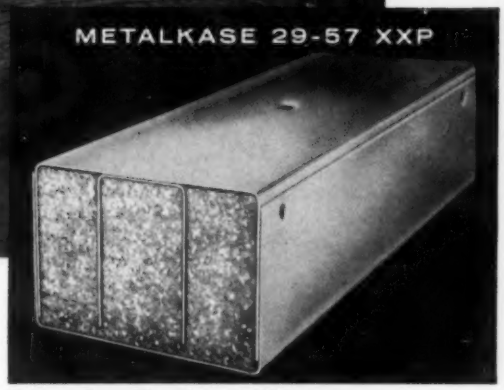
QUOTATIONS FROM LITERATURE OF LONG AGO ILLUSTRATE HARBISON-WALKER'S LEADERSHIP

The Original METALKASE Basic Brick. From Harbison-Walker Manual 1916: "METALKASE BRICK, a refractory of ingenious form, developed and perfected through several years' service in actual open hearth practice. After its value in open hearth linings had been completely demonstrated, it was first placed on the market in 1916. These brick have been adopted with highly satisfactory results in many steel plants and under conditions for which they are best suited have given two to three times the service of magnesite brick and many times that of silica brick."

The First Suspended Basic Roof built for Harbison-Walker's pioneering research in 1931. From AIME Proceedings, Volume 106 (1933): "Almost nothing was known regarding the behavior of magnesite brick in suspended construction; the time required for safe heating and cooling, limiting temperatures at which hot patching could be attempted; the effects of relatively high thermal conductivity on hangers; probable heat losses; or the possibility of insulation. In order to secure needed data, an experiment was conducted at the plant of Harbison-Walker Refractories Company at Hays, Pa."

in 1923 . . . Chemically Bonded Basic Brick — In the year 1923 Harbison-Walker introduced the first chemically bonded magnesite-chrome refractory for which patents were granted in 1925. Through ensuing years, many millions of chemically bonded basic brick, a major portion of which were made with the metal casings, have become used as the standard type of basic brick in open hearth steel furnaces.

These important milestones of progress in basic refractories are typical of many others by Harbison-Walker.



Sprung Open Hearth roof of METALKASE 29-57 XXP at Homestead Works of United States Steel Corporation.

TODAY ...

Another Harbison-Walker Basic Open Hearth Roof among the many making service and tonnage records

With the all-basic open hearth furnace becoming an economical reality the production of new refractories having decidedly enhanced properties has been necessary. Harbison-Walker conventional and specialized basic refractories are fully meeting these requirements.

A fundamental factor in the achievement of the all-basic furnace is the metal encased basic brick pioneered more than forty years ago by Harbison-Walker. Through constant research and extensive application experience, rapid evolutionary progress has resulted in the successful use of the metal encased brick for the open hearth roofs as well as for other furnace parts. METALKASE 29-57 XXP internally plated metal encased brick are used in both sprung and suspended open hearth roof constructions of all designs with excellent service records.

An exceedingly important contributor to the excellence of this refractory developed specifically for this requirement, is the high purity magnesia produced by Harbison-Walker from Michigan brines. Fully stabilized as periclase of high density, it is an important constituent of this refractory having outstanding properties for the particular application.

The successful use of basic brick for roofs contributes to greater severity of conditions imposed upon other furnace parts. Harbison-Walker basic refractory products long established with unequalled records, together with the newer specialized brands, fulfill these rigid requirements for bottoms — walls — and regenerator checkers and make the ALL-INCLUSIVE, ALL-BASIC Open Hearth Steel Furnace a reality.

HARBISON-WALKER REFRACTORIES CO.

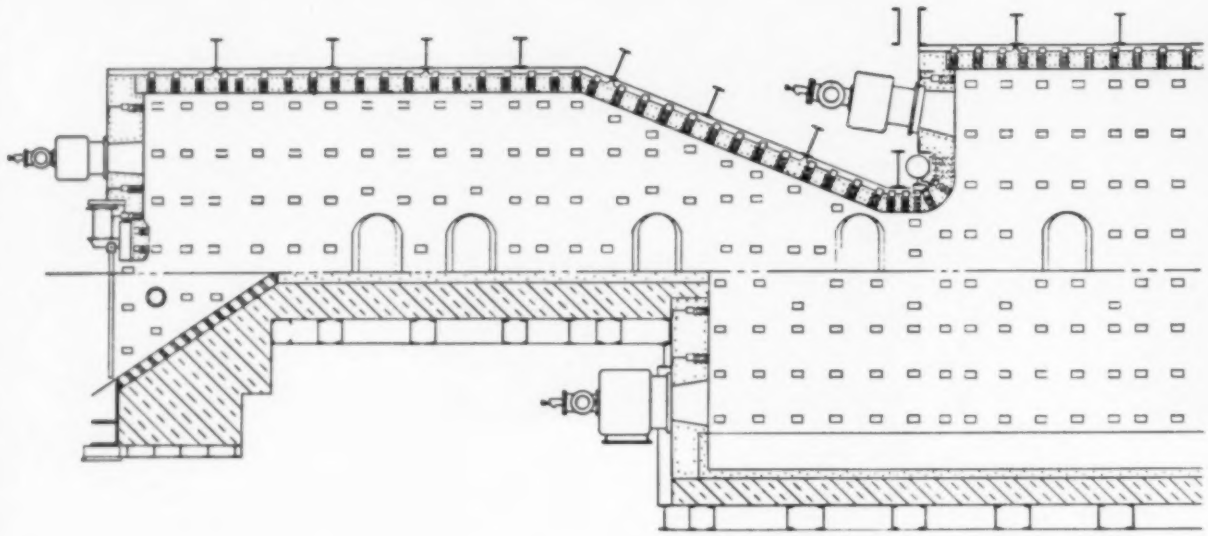
and Subsidiaries

General Offices: Pittsburgh, Pennsylvania

World's Most Complete Refractories Service

CONCEIVED BY THE FURNACE BUILDERS — ACHIEVED BY RAMTITE®

"SIMPLICITY" *is the keynote of this*



a RAMTITE® *installation in a*

The construction was so simple, it required only one type of anchor for this entire furnace!

In December, 1958, this RAMTITE installation was completed.

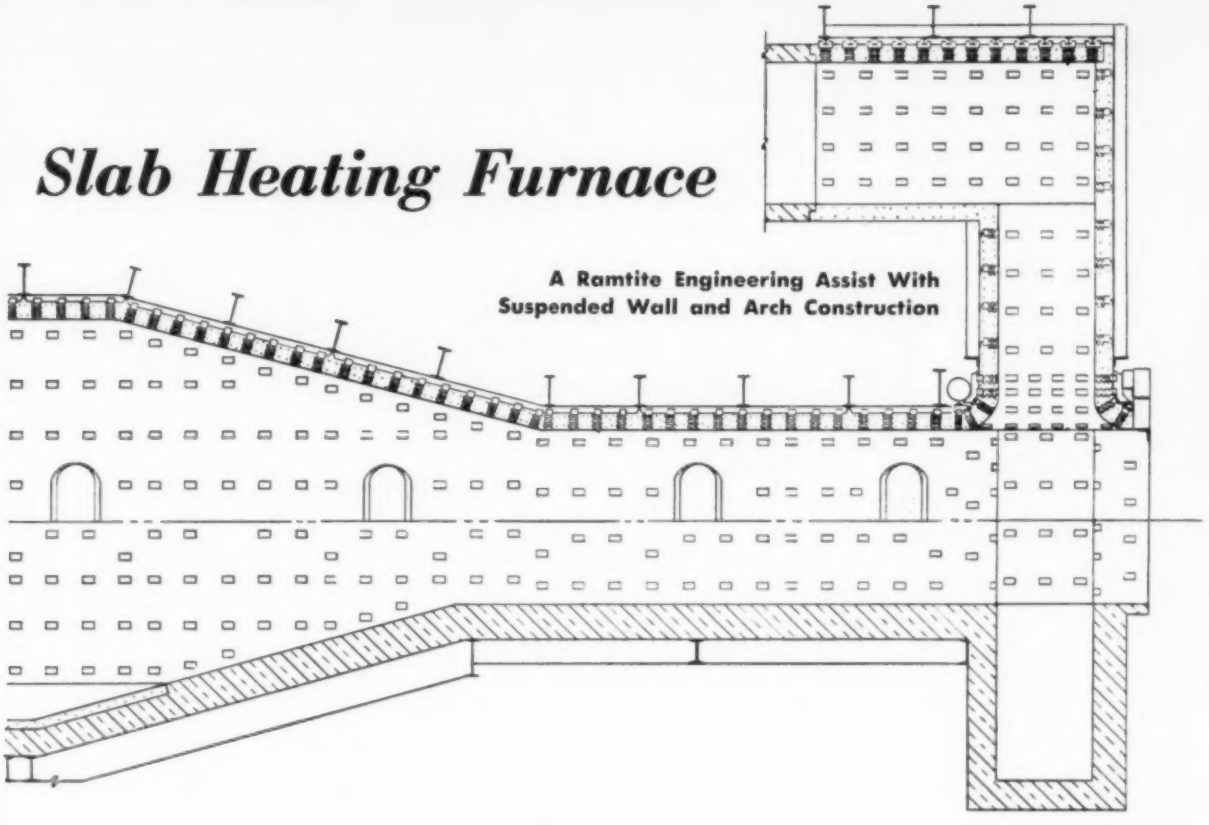
RAMTITE, the plastic refractory, was used for the complete enclosures. This included suspended sidewalls, burner walls, flat suspended arch, uptake walls, recuperative walls and the flat suspended walls leading to the recuperative entrance.

By using this monolithic construction the loss of heat will be greatly decreased. And there are numerous other advantages!

— proving that RAMTITE® is our business
— not a sideline
It has been built on PERFORMANCE!

Slab Heating Furnace

A Ramtite Engineering Assist With Suspended Wall and Arch Construction



foreign steel plant's new furnace

The unique feature of this project is its method of anchorage. Only a single type anchor was used. This saved money in buying and the intricate installing of dozens of shapes. It also saves inventory of so many refractories and the necessary storage space required.

The Ramtite Co. offers you a complete sales engineering service. Experienced men are always available to study your refractory problems and consult with your Engineering, Mason and Ceramic Departments about your specific needs.

Contact your local or nearby Ramtite representative or write us today for further information. (The bulletins mentioned below may be of particular interest. Send for them. Use the handy coupon.)

The Ramtite Co.
DIV. OF THE S. OBERMAYER CO.
1811 South Rockwell St. Chicago 8, Ill.

THE RAMTITE CO., Div. of The S. Obermayer Co.
1811 South Rockwell St., Chicago 8, Illinois

Please send the items checked:

- ☐ We are interested in Ramtite. Please send information.
- ☐ Bulletin on Castable and Gunning Refractories
- ☐ Steel Plant Bulletin

Company Name_____

Attn. Mr. _____ Title_____

Address_____

City_____ Zone____ State_____

Expanding the Frontiers of Space Technology

Advancement in missile and space technology is highly dependent on metallographic research being conducted at Lockheed today. Special programs include the study of high and low temperature materials, radioactive and toxic materials, pure metals, properties of beryllium and the alloys, and the development of refractory and special-purpose metals, cermets and ceramics.

Studies are also being made of the creep of materials under high temperatures over very short periods – 15 seconds or less; materials testing in hot flow gases; powder metallurgy; metal working and heat treating; high temperature and vacuum techniques; electron bombardment melting; corrosion and gas-metal reactions; gas solubilities in solids; reaction mechanisms at interfaces; impurities and imperfections; deformation; fracture; x-ray and electron diffraction; and diffusion.

Scientists and engineers of outstanding talent and inquiring mind are invited to join us in the nation's most interesting and challenging basic research programs. Write to Research and Development Staff: Dept. D-55, 962 W. El Camino Real, Sunnyvale, California.

"The organization that contributed most in the past year to the advancement of the art of missiles and astronautics." NATIONAL MISSILE INDUSTRY CONFERENCE AWARD.

Lockheed

MISSILES AND SPACE DIVISION

SUNNYVALE, PALO ALTO, VAN NUYS,
SANTA CRUZ, SANTA MARIA, CALIFORNIA
CAPE CANAVERAL, FLORIDA • ALAMOGORDO, NEW MEXICO

Metallurgists Wanted

The US Bureau of Mines is accepting applications for the position of metallurgist. These positions are located in modern and complete laboratories with excellent equipment for research and development. Work in diversified programs of national importance in the fields of mineral dressing, extractive and physical metallurgy. Most positions are with the Bureau in Minnesota, South Dakota, and Missouri. Starting salaries range from $374 to $734 a month. Additional information may be obtained from the *Executive Secretary, Board of US Civil Service Examiners, Bureau of Mines, Rolla, Mo.*

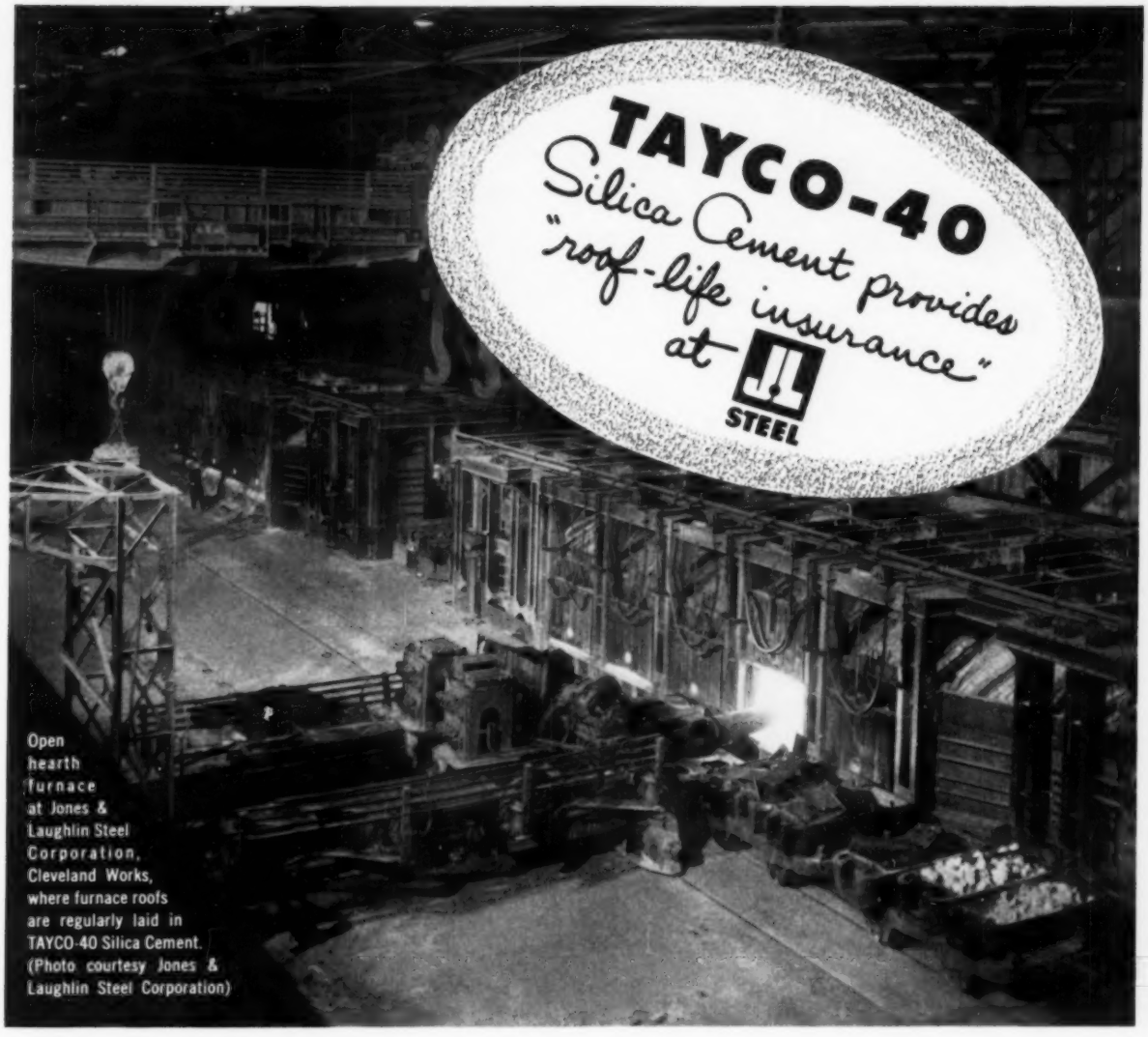
By Ned Landon, as quoted by Dr. Guy Suits in an address before the Scientific Research Society of America.

The Chief Executive's Utterly Exact Method for Measuring Scientific Research

I multiply your projects by the words I
can't pronounce,
And weigh your published papers to the
nearest half an ounce;
I add a healthy bonus for research that's
really pure
(And if it's *also* useful, your job will be
secure).

I integrate your patent-rate upon a monthly
basis
And I figure what your place in the race to
conquer space is;
Your scientific stature I weigh upon some
scales
Whose final calibration is the company's
net-to-sales.

And so I create numbers where there were
none before;
And thus have facts and figures and formulae galore—
And these volumes of statistics make the
whole thing very clear:
Our research should cost *exactly* what
we've budgeted this year!



Open hearth furnace at Jones & Laughlin Steel Corporation, Cleveland Works, where furnace roofs are regularly laid in TAYCO-40 Silica Cement. (Photo courtesy Jones & Laughlin Steel Corporation)

At Jones & Laughlin Steel Corporation, Cleveland Works, as well as at other leading steel mills in the United States, TAYCO-40 Silica cement is regularly used to obtain tight, weld-like joints in silica open hearth furnace roofs.

TAYCO-40 is nearly as refractory as the best grades of silica or super-duty silica brick. Because of its excellent water-retention properties, TAYCO-40 is smooth working — remains plastic longer — making it the most workable, easy-to-use silica cement available. These properties are obtained without the addition of plastic fire clays found in ordinary silica mortars.

TAYCO-40 is also highly recomended for use with silica and semi-silica brick and silica stone in soaking pits; with semi-silica brick in open-hearth regenerator walls and roofs. Try TAYCO-40 for your next rebuild. Ask your Taylor field engineer, or write direct, for full details.

Exclusive Agents in Canada:
REFRACTORIES ENGINEERING AND SUPPLIES, LTD.
Hamilton and Montreal

TAYLOR ZIRCON TAYLOR SILLIMANITE

The **CHAS. TAYLOR SONS Co.**
A SUBSIDIARY OF NATIONAL LEAD COMPANY
REG. U. S. PAT. OFF.
REFRACTORIES SINCE 1864 • CINCINNATI • OHIO • U. S. A.

Personnel

(Continued from page 210)

Research and Development Director, extensive background in thermo, combustion, metallurgy, and nuclear reactors. Executive to take results and convert into a salable product in the field of pressure vessels, heat transfer, equipment, etc. Salary to $25,000 year. Location, East. W6990.

Chief Industrial Engineer, graduate, for multi-plant operations in the very heavy metal industry, including welding, machine shop, and foundry. Should have background in cost estimating, especially large job shop costs. Salary to $25,000 year. Location, East. W6989.

Metallurgical Engineers for Research and Development Laboratory, B.S. or M.S., Met.E., or Welding, experienced in fabrication of ferrous and non-ferrous light metals. One with special experience in joining problems (welding, brazing, soldering); one with special experience in metallurgy of magnesium castings. Work in metallurgical and metal finishing group. Salary open. Location. Los Angeles County. S4160.

Process Metallurgists, Ch.E. or Process Metallurgy, with some experience in research in non-ferrous extractive metallurgy, to work on special research for pilot plant design and operation. Spanish helpful. Location, Cuba. W4163.

Research Engineers. (a) Physical Metallurgists, Ph.D or M.S., with research experience. Interested in (1) crystal orientation, or (2) macro and microstresses, or (3) annealing problems, or (4) high-temperature materials, or (5) alloy department, or (6) general physical metallurgy. (b) Physicist or Metallurgist, B.S., with electron microscopy experience on metals. (c) Physicist or Metallurgist, B.S., with X-ray diffraction experience on metals. (d) Chemical Engineer or Metallurgist, B.S. or M.S., with strong background in thermodynamics, heat transfer, for work in steelmaking process development. (e) Physicist, M.S., with background in instrumentation and control. (f) Electronic Engineer, B.S., with pulse or video circuit background. (g) Corrosion Engineer,

(Continued on page 222)

PROMINENT WEST GERMAN ALLOY STEEL COMPANY SEEKS PRACTICAL OPERATORS OR CONSULTANTS.

1—EXPERIENCED ROLLING MILL ENGINEER TO SUPERVISE AND/OR OPERATE COLD STRIP MILL ROLLING STAINLESS QUALITIES.

2—EXPERIENCED ENGINEER FOR SIMILAR WORK COLD ROLLED SILICON ELECTRICAL QUALITIES.

WOULD CONSIDER SENIOR OR RETIRED APPLICANTS WHO MIGHT CARE TO SPEND ONE OR TWO YEARS WHOLLY OR PARTLY ABROAD.

Box 6-JM AIME

29 West 39th St. New York 18

Goose Lake
Ladle Brick
Line your iron and steel ladles with Goose Lake Fire Clay Ladle Brick! Produced by the dry press method with a special de-airing process, Goose Lake Brick assures excellent resistance to basic slags, spalling and abrasion. It is well burned to provide high density, low porosity and uniform dimensions.
a product of
ILLINOIS CLAY PRODUCTS COMPANY
Main Office: Barber Building Joliet, Illinois
Sales Office: 208 South LaSalle Street Chicago, Illinois

"UNION CARBIDE METALS *is working with us on columbium-treated carbon steels"*

The effect of columbium in improving the strength and weldability of mild carbon steels was discovered in 1936 by UNION CARBIDE METALS (U. S. Patent No. 2264355). This discovery was made available to the steel industry. Now, long-standing government restrictions on using columbium have been removed. Columbium is in plentiful supply. New ore sources and refining processes have been found.

UNION CARBIDE METALS is therefore conducting a further extensive evaluation of columbium-treated steels. Results of this continuing investigation will also be made available to the steel industry. For information on columbium, contact UNION CARBIDE METALS, pioneer in the production of highly soluble, high-purity ferrocolumbium since 1935.

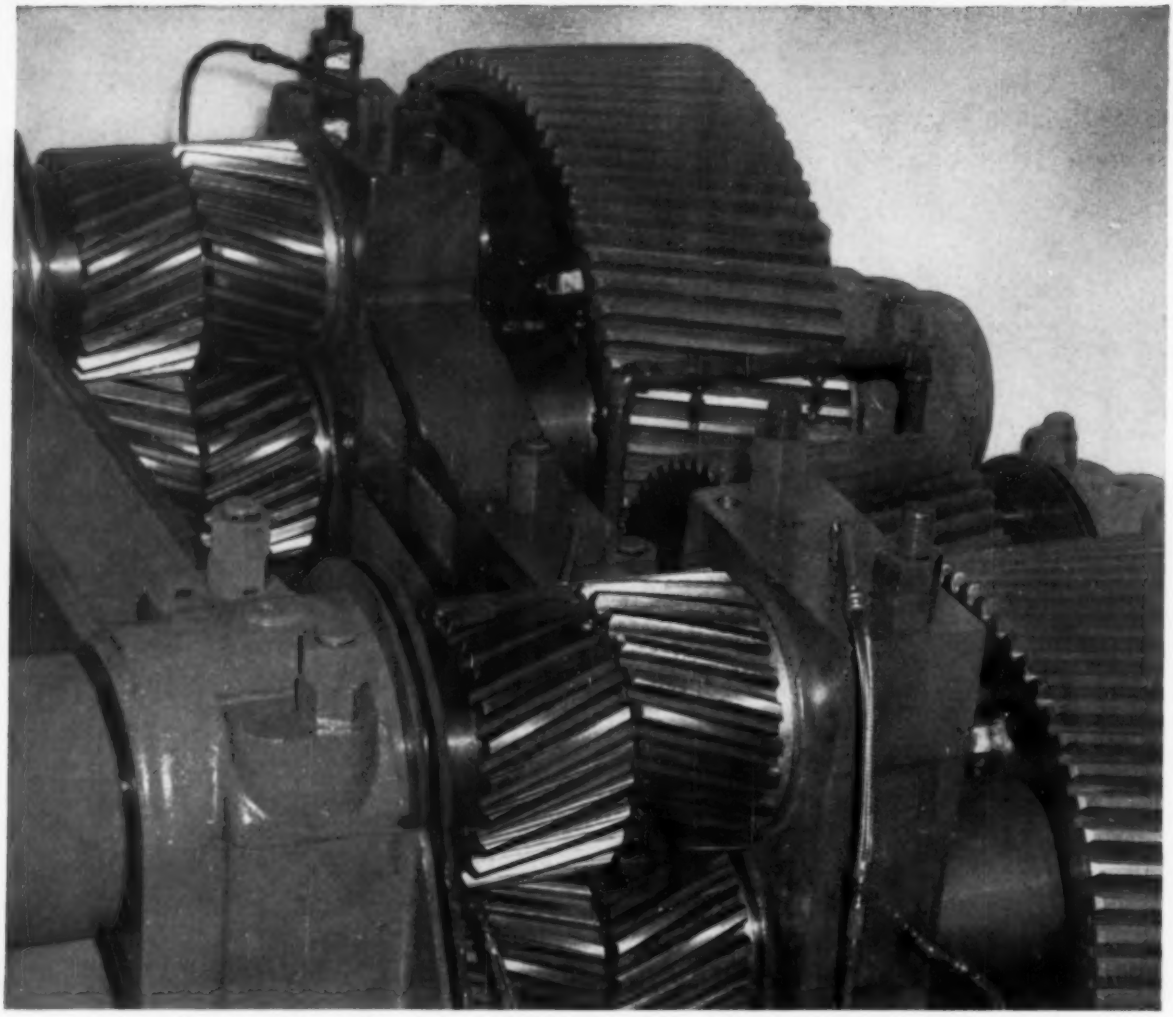
UNION CARBIDE METALS COMPANY, Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y.

ELECTROMET ferrocolumbium is offered in pre-weighed bags for accurate additions to the ladle or ingot molds.

UNION CARBIDE METALS

Electromet *Brand Ferroalloys and other Metallurgical Products*

The terms "Electromet" and "Union Carbide" are registered trade-marks of Union Carbide Corporation.



Rolling mill pinions of Type 4620 nickel-molybdenum steel have a good hard case (500/550 Brinell) plus toughness, stand up to severe overloads. Made by Morgan Construction Company, Worcester, Mass.

4620 Nickel alloy steel gives them 4 times longer service

Hardened rolling mill pinions in an Eastern steel plant were not giving satisfactory service, due to continuous overloading. They just weren't tough enough to take the beating of heavy rolling.

Designers solved the problem – called for pinions of 4620 nickel-moly carburized steel ground after hardening. Now they've got a good case – pinions don't crack . . . tough cores support them.

This case stood up – the 4620 nickel alloy steel pinions have served over *4 times longer* than the old through-hardened pinions . . . and are still going strong.

This high-performance pinion was *not* difficult to make. It was rough-machined at a hardness of 187/220 Brinell; showed little distortion through carburizing and hardening. Only 0.005" was needed for finish grinding, after hardening to 500/550 Brinell.

Parts that take a beating in heavy equipment must also have practical service life – you get both in nickel alloy materials.

For practical information on 4620 nickel alloy steel and its application to your specific metal problems, write Inco's Development and Research Division.

THE INTERNATIONAL NICKEL COMPANY, INC.
67 Wall Street INCO New York 5, N. Y.

INCO NICKEL
NICKEL ALLOYS PERFORM BETTER LONGER

Commercial production of rhenium metal

Commercial production of wrought rhenium rod, wire, and strip is presently being scheduled by the research and development dept. of Chase Brass & Copper Co., a subsidiary of Kennecott Copper Corp. Extremely pure rhenium powder is pressed into bars at 25 to 30 tons psi. The bars are presintered at 1200°C under vacuum, followed by resistance sintering in a hydrogen atmosphere. Temperature of the bar is raised to 2800°C for a period of time determined by the size of the bar. Final density ranges from 90 to 96 pct of theoretical density.

All fabrication is done by cold working, difficult because of the rapid rate of work hardening of the metal. Rhenium is an extremely dense, silver-colored material with a high melting point and high strength at elevated temperatures. Not a structural metal, rhenium's greatest potential use is as a welding material for molybdenum, either in its pure state or alloyed with molybdenum. Main sources of supply in the US at the present are Kennecott's western ore deposits. Potential production capacity of the US is estimated at 20,000 to 30,000 lb per year.

Copper-tantalum bonding method developed

Stanford Research Institute has developed a new technique for bonding copper to tantalum, thus combining the corrosion resistance of tantalum and the heat conductivity of copper at temperatures up to 3600°F. It is one of several high-temperature research projects completed by Stanford last year.

OLP steelmaking process successful

The Denain works of USINOR is currently employing the OLP (oxygen, lime-powder) process developed by IRSID, the French Steel Research Institute (see Journal of Metals, July 1958, p. 466). USINOR has already produced more than 10,000 tons of steel using this commercial process, and it is claimed that the steel is consumer-accepted as a grade equivalent to high-grade, open-hearth steel. Additional USINOR equipment is available to increase production by the OLP process, which blows molten pig iron with lime-powder in suspension in pure oxygen.

UCC triples ductile vanadium capacity

The increasing use of vanadium as a structural metal, predicted by UCC Vice President Augustus B. Kinzel 10 years ago, has been borne out by an expansion of production facilities for high-purity vanadium at Union Carbide Metals Corp., div. of Union Carbide Corp. Since 1949 when Dr. Kinzel announced that the company had become the first producer of high-purity, ductile vanadium in industrial forms and quantities, Union Carbide has been producing the metal in forms for remelting, as well as mill products such as plate, sheet, rod, wire, and foil.

Electron beam welders unveiled

Production welders utilizing the concentrated energy of a focused beam of high-velocity electrons to weld metals have been unveiled by High Vacuum Equipment Corp., Hingham, Mass., and Air Reduction Sales Co., div. of Air Reduction Co. Inc., New York. The use of electrons in welding is possible only in a high vacuum, which makes it impossible for the metals to be contaminated by the atmosphere during the welding process. Using this process it will be possible to weld tungsten, tantalum, or molybdenum to each other or to other metals, with results previously unobtainable.

Built by
HEVI-DUTY
specialists in
electric furnaces

Versatile salt bath furnace has extra pot...will travel

Versatility and portability are the chief advantages of this immersed electrode Hevi-Duty salt bath furnace at Clevite Research Center in Cleveland. Since work here is experimental, the furnace must be used on a wide variety of operations. It is equipped with a welded steel pot for low-temperature heat treating and an interchangeable ceramic pot for temperatures up to 2300° F.

The furnace is coupled with a transformer and mounted on rollers so that it may be used anywhere in the shop.

Perhaps this combination of adaptability and portability can fit into your operation — and save you the cost of two or more specialized furnaces.

Write for Bulletin 655 for further information about Hevi-Duty salt bath furnaces, or outline your particular problem.

- Heat Processing Furnaces
- Dry Type Transformers
- Constant Current Regulators

HEVI-DUTY ELECTRIC CO.
Milwaukee 1, Wisconsin

TECHNICAL LIBRARIAN

To establish and supervise operation of Research and Development Laboratory of major metal producer in the Pittsburgh area.
Degree in Science or Engineering required. Reading knowledge of one or more foreign languages helpful.
Applications will be regarded as confidential. Please include photograph with resume of training and experience.

Box 7-JM AIME
29 West 39th St. New York 18

Personnel

(Continued from page 218)

M.S. or Ph.D for research in stainless steel corrosion problems. Location, western Pennsylvania. W7073.

Metallurgist, graduate, with considerable experience in making brazing alloys for new plant starting in this field. Salary open. Location, New York Metropolitan area. W7050.

Precision Casting Engineer with metallurgical background and practical foundry experience. Location, Long Island, N. Y. W7045.

Mechanical Engineer or Physical Metallurgist, degree in mechanical or metallurgical engineering with experience in fuel burner or high-temperature boiler design evaluation. Will involve a concentration of development problems for fuel burners. Will be responsible for studies of high-temperature materials and material properties at high temperatures; will also develop fabrication techniques for materials subjected to high-temperature environment. Also included will be an evaluation of the physical properties of materials, heat transfer, and the effects of radiation. Salary, $8000 to 11,000 year. Location, upstate New York. W7015.

Research Metallurgist, Met.E or M.E., with background in metallurgy for studies in properties of hard metals. New laboratory being set up. Permanent. Opportunity. Salary, $7200 to 9000 year. Location, San Francisco Peninsula. S4142.

Metallurgists. (a) Research Metallurgists with good background in inorganic chemistry, one to ten years experience. Will lead or assist in projects in hydro-metallurgy, pyrometallurgy, and mineral beneficiation. Salary open. (b) Physical Metallurgist with five to ten years experience. Background in powder metallurgy and related fields of particular interest. Will head up projects. Salary open. Location, western Canada. F6652.

GENERAL REFRACTORIES

GREFCO INTERNALLY PLATED BASIC BRICK HELPS BREAK STEEL PRODUCTION RECORDS

● General Refractories developments—starting with the RITEX process—have steadily kept pace with the advance of American steelmaking. As new methods of furnace construction placed continuously greater demands on refractories, Grefco produced, in turn, progressively tougher, more durable, more serviceable refractory brick. Grefco's RITEX pioneered the field of chemically bonded basic brick; STEELKLAD was the first brick with integral metal encasement; FERROCLIP and TAB brick answered the need for brick positioned by mechanical means.

To meet demands for ever-higher operating temperatures to speed steel production, Grefco introduced the revolutionary EE *internally-plated* basic brick. Permitting a phenomenal growth in the number of "All-Basic" open hearth furnaces, and capable of withstanding the far more punishing heating-and-cooling cycles of modern, heavy-oxygen steel production, *The GREFCO "EE" HAS MADE POSSIBLE A DEVELOPMENT BREAKTHROUGH IN STEELMAKING.* Most significantly, the world's open hearth steel production record, exceeding 100 tons per hour, was recently established by a Grefco-equipped "All-Basic" furnace.

Through constant research and development of new and improved products, Grefco maintains its traditional leadership in the field of basic open hearth refractories.

• • •

Grefco technical and sales service personnel are ready to help you build simplified basic furnaces, whether of sprung, suspended, or combination roof construction. Please contact them, without obligation.

GENERAL REFRACTORIES COMPANY, Philadelphia 2, Pa.

A Complete Refractories Service

Photo courtesy of Jones & Laughlin Steel Corporation

BAKER'S MAGDOLITE AND JEBCOLITE
are always 5 ways better

Continued research and development throughout the years, plus The J. E. Baker Company's precisely controlled manufacturing methods, have resulted in the superior, properly burned, grain-sized Magdolite and Jebcolite particles which help provide:

More uniform ingots—increased ingot production—increased furnace efficiency—lower refractory costs—less defective production material.

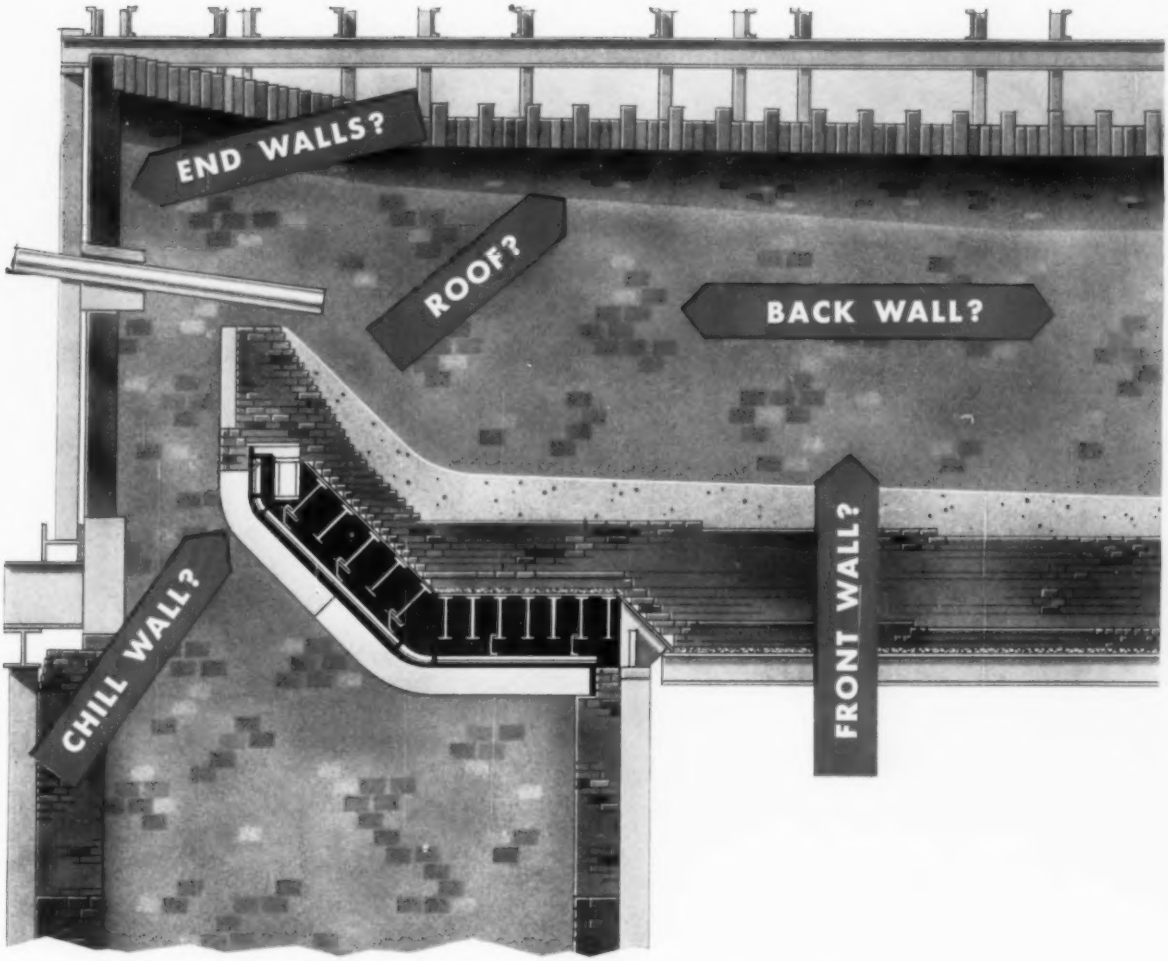
Magdolite and Jebcolite* are the *original* dead-burned dolomites that offer better composition, preparation, strength, economy and quality. Don't say "dolomite." Save dollars. Specify Baker's Magdolite for open hearth and Jebcolite for electric furnace use.

** Jebcolite has the same superior chemical, physical and mineralogical characteristics as Magdolite and differs only in grain size which is designed specifically for electric furnace application.*

JEBCO
PRODUCTS
SINCE 1889

THE J. E. BAKER COMPANY
YORK, PENNSYLVANIA
PLANTS: BILLMEYER, YORK, PENNSYLVANIA — MILLERSVILLE, OHIO

WHERE ARE THE TROUBLESOME WEAR AREAS IN YOUR FURNACE?



HOW TO GET MORE OUT OF YOUR FURNACE WITH CORHART 104!

CORHART 104 Electrocast is a basic refractory tailored to help you "beef up" the troublesome wear areas. It has already proved that it can increase furnace availability, reduce repair shut-downs in the most vulnerable spots of open hearths.

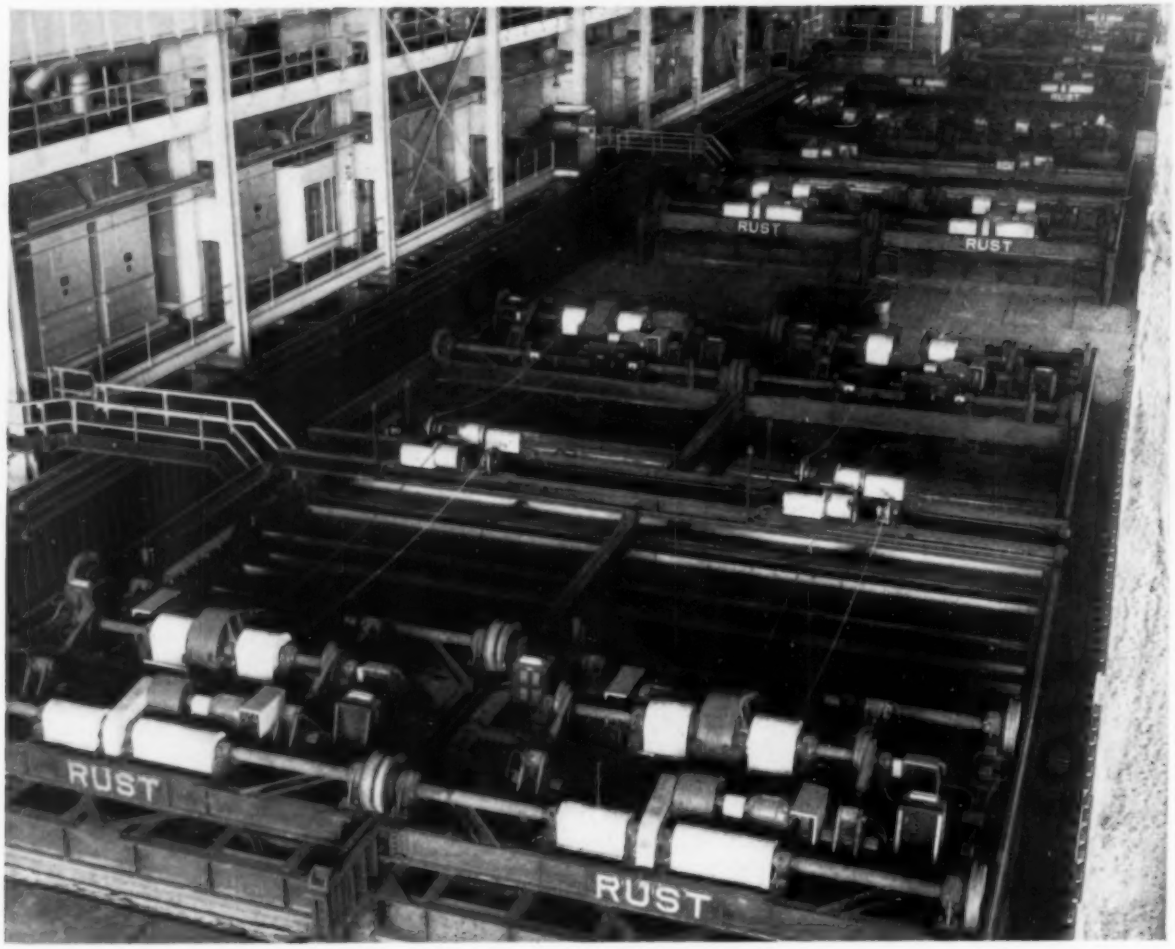
Corhart engineers will welcome the chance to inspect your furnace and make suggestions. For further information please write: Corhart Refractories Company, Incorporated, 942 Commonwealth Bldg., Louisville, Kentucky.

CORHART 104
ELECTROCAST
REFRACTORY

Subsidiary of Corning Glass Works

The words "Corhart" and "Electrocast" are registered Trade Marks which indicate manufacture by Corhart Refractories Company, Incorporated

Morgan-Isley Systems WITH SECONDARY CHECKERS IN BASES OF EJECTORS



. . . Enable large Eastern Steel Plant to use 106 Btu per cubic foot mixed blast furnace and coke oven gas in sixteen holes of cross-fired regenerative soaking pits. Checker system preheats combustion air to 2000°F. or higher.

Simple, completely modern temperature and combustion controls with automatic reversal insure rapid, efficient heating with excellent uniformity from top to bottom of ingots.

This plant also has twenty-four other holes of soaking pits equipped with the Morgan-Isley System using 117 Btu per cu. ft. gas.

Morgan-Isley Systems are in use on soaking pits using the complete range of fuels from straight blast furnace gas up to and including natural gas and oil.

Modernize your soaking pits with Morgan-Isley—consult us about your requirements.

MORGAN WORCESTER

MORGAN CONSTRUCTION COMPANY
WORCESTER, MASSACHUSETTS
ROLLING MILLS • MORGOIL BEARINGS • WIRE MILLS
GAS PRODUCERS • EJECTORS • REGENERATIVE FURNACE CONTROL

CCC 58

education

NUCLEAR RESEARCH

► **The Pennsylvania State University** will hold a seminar from June 1st to 26th on the use of *nuclear reactors and radioisotopes in research and development.* Opportunities will be provided for discussion and analysis of problems of interest to the individual in his own professional work. A technical background equivalent to a B.S. degree in engineering or physical science is essential for profitable participation. For information write to *Mr. Forrest J. Remick, Research Associate, The Pennsylvania State University, University Park, Pa.*

► **The Atomic Energy Commission** announces a new program of assistance to colleges and universities for *education and training in radioisotope principles and technology.* The purpose of the program is to foster the widespread use of radioisotopes through the training of scientists, engineers, and technicians. Direct assistance in obtaining demonstration apparatus, student lab equipment, and training aids is provided. Submit proposals and requirements to *Director, Office of Isotopes Development, U. S. Atomic Energy Commission, Washington 25, D. C.*

► **University of California** has been granted $80,000 by the AEC for the purchase of equipment to be used in industrial radioisotope training.

CORROSION & SPECTROSCOPY

► **Massachusetts Institute of Technology** offers a summer course on corrosion from June 22nd to 26th. Material to be covered includes the techniques for measuring and calculating potentials and polarization, corrosion rates from polarization data, and potential criteria of cathodic protection. Lectures and informal seminars will be given. Tuition is $200.

Offered concurrently by MIT is a course on the *technique of infrared spectroscopy* intended primarily for those interested in experimental aspects of the subject. Lectures, conferences, and lab work will total about 30 hours. Tuition is $175.

From June 29th through July 3rd, MIT has scheduled sessions on *application of infrared spectroscopy.* Special attention will be given to chemical fields in which infrared spectra have proved of value. The course will deal with the theory of infrared absorption by molecules, the interpretation of infrared spectra, and the use of infrared methods in chemical analysis. Tuition is $175. For details about MIT courses, write to *Prof. James M. Austin, Director of the Summer Session, Massachusetts Institute of Technology, Cambridge 39, Mass.*

PLASTICS AND SINTERING

► **The Pennsylvania State University's** *plastics engineering seminar,* to be given from June 28th to July 3rd, will hold discussions on chemistry, physics, and mechanical properties of high polymers; theory of viscoelasticity; design of parts made of plastics; and plastics under special service conditions such as elevated temperatures, radiation, and high-speed loading. Emphasis will be placed upon new developments in high polymers and plastics engineering, evaluation of experimental results, and service information and their applications to design. Information may be obtained from the *Extension Conference Center, The Pennsylvania State University, University Park, Pa.*

► **The University of Notre Dame,** Dept. of Metallurgy, is organizing a conference on *Sintering and Related Phenomena,* to take place on June 15th to 17th. The aim of the conference is to gather together the chemists, engineers, and physicists who are interested in sintering phenom-

(Continued on page 234)

Robinson Refractories Serve You Best!

No matter what your requirements, it pays to specify Robinson Refractories

- ★ Advanced production techniques
- ★ Modern manufacturing equipment
- ★ Rigid quality control
- ★ Field engineering service
- ★ 15 completely stocked branches
- ★ Fast, dependable delivery
- ★ Complete line for all your needs

New! Robinson Kiln Car and Floor Block. Write for Complete-Line Refractories Catalog.

THE ROBINSON CLAY PRODUCT CO. ESTABLISHED 1856 AKRON 9, OHIO

15 ROBINSON BRANCHES TO SERVE YOU BEST

AKRON, OHIO • ALBANY, N. Y. • BALTIMORE, MD. • BLOOMFIELD, N. J. • BOSTON, MASS. • BUFFALO, N. Y. • CHICAGO, ILL. • EAST HARTFORD, CONN. • INDIANAPOLIS, IND. • MT. VERNON, N. Y. • NEW YORK, N. Y. (JAMAICA, L. I.) • PHILADELPHIA, PA. (POTTSTOWN, PA.) • ROCHESTER, N. Y. • SYRACUSE, N. Y. • CONCORD, ONTARIO, CANADA

R 359-1368

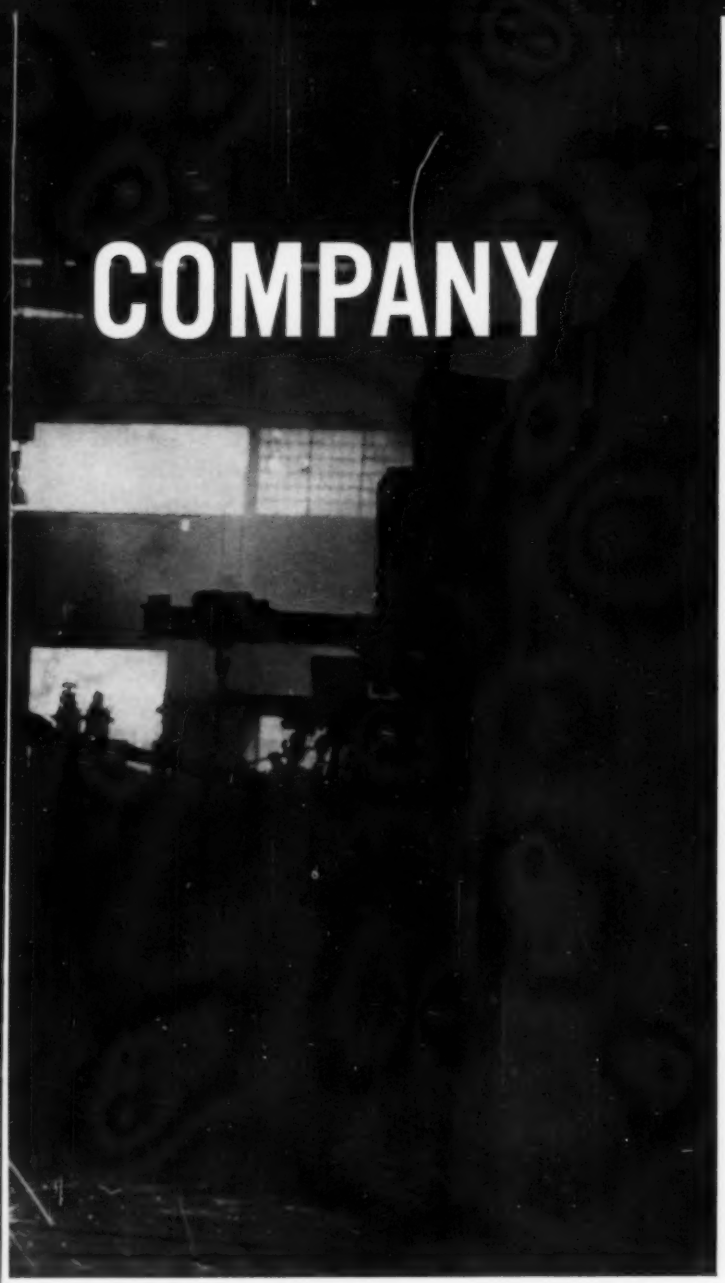
NOW IT'S UNION CARBIDE METALS

Production Plus: A dependable supply of ferroalloys and metals is assured from six modern plants (three with their own power facilities) and seventeen warehouses.

Product Variety: More than 100 top-quality ELECTROMET brand ferroalloys and metals are available from Company plants such as this at Marietta, Ohio.

Research: The Metals Research Laboratories at Niagara Falls, N.Y. is one of the largest metallurgical research and development centers in the world.

Customer Service: Some of the country's best-qualified specialists in the proper use of alloying materials provide technical service to customers.



Known for over 50 years as
ELECTRO METALLURGICAL COMPANY, we have changed our name to Union Carbide Metals Company. This name will reflect more accurately the close association of this Division with Union Carbide Corporation.

This is a change in name only. The products, the people, and the earnest desire to serve you remain the same.

Our metals laboratories with a 500-man team of metallurgists, engineers, and technicians are carrying out extensive research and development programs in ferroalloys, pure metals, and metal chemicals. Technical assistance and other specialized services are available from our competent metallurgical staff. In addition, Union Carbide Metals Company is backed by the diversified resources of all the other divisions of Union Carbide Corporation. These are only a few of the many reasons why you will continue to get more for your money when you buy the familiar ELECTROMET brand products.

PRODUCTS OF UNION CARBIDE METALS COMPANY INCLUDE

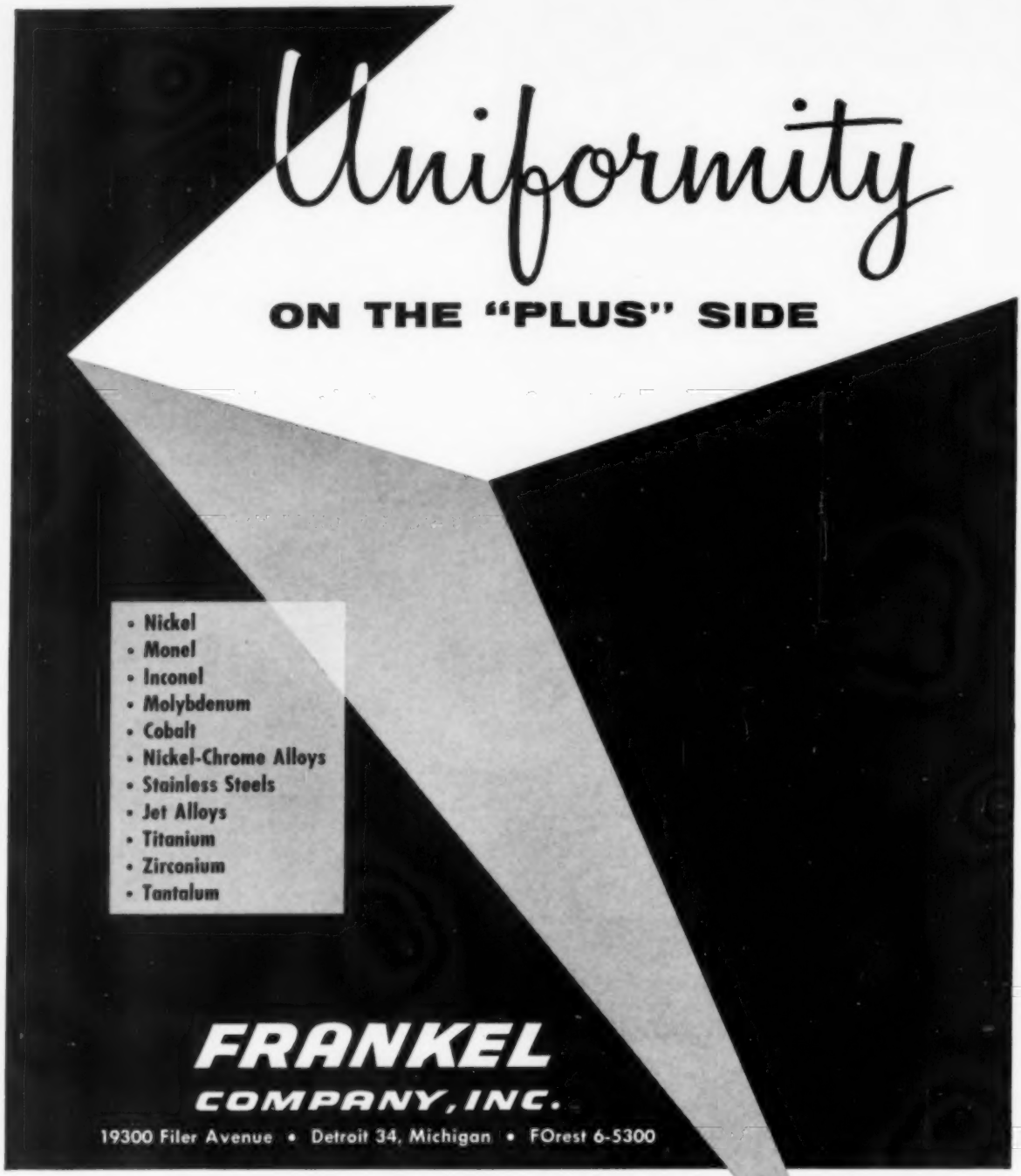
Electromet **Ferroalloys and Metals: Boron, calcium, chromium, columbium, manganese, silicon, tantalum, titanium, tungsten, vanadium, and zirconium. Also metal chemicals and metal compounds.**

UNION CARBIDE METALS

Electromet **Brand Ferroalloys and other Metallurgical Products**

UNION CARBIDE METALS COMPANY
Division of Union Carbide Corporation, 30 East 42nd Street, New York 17, N. Y.

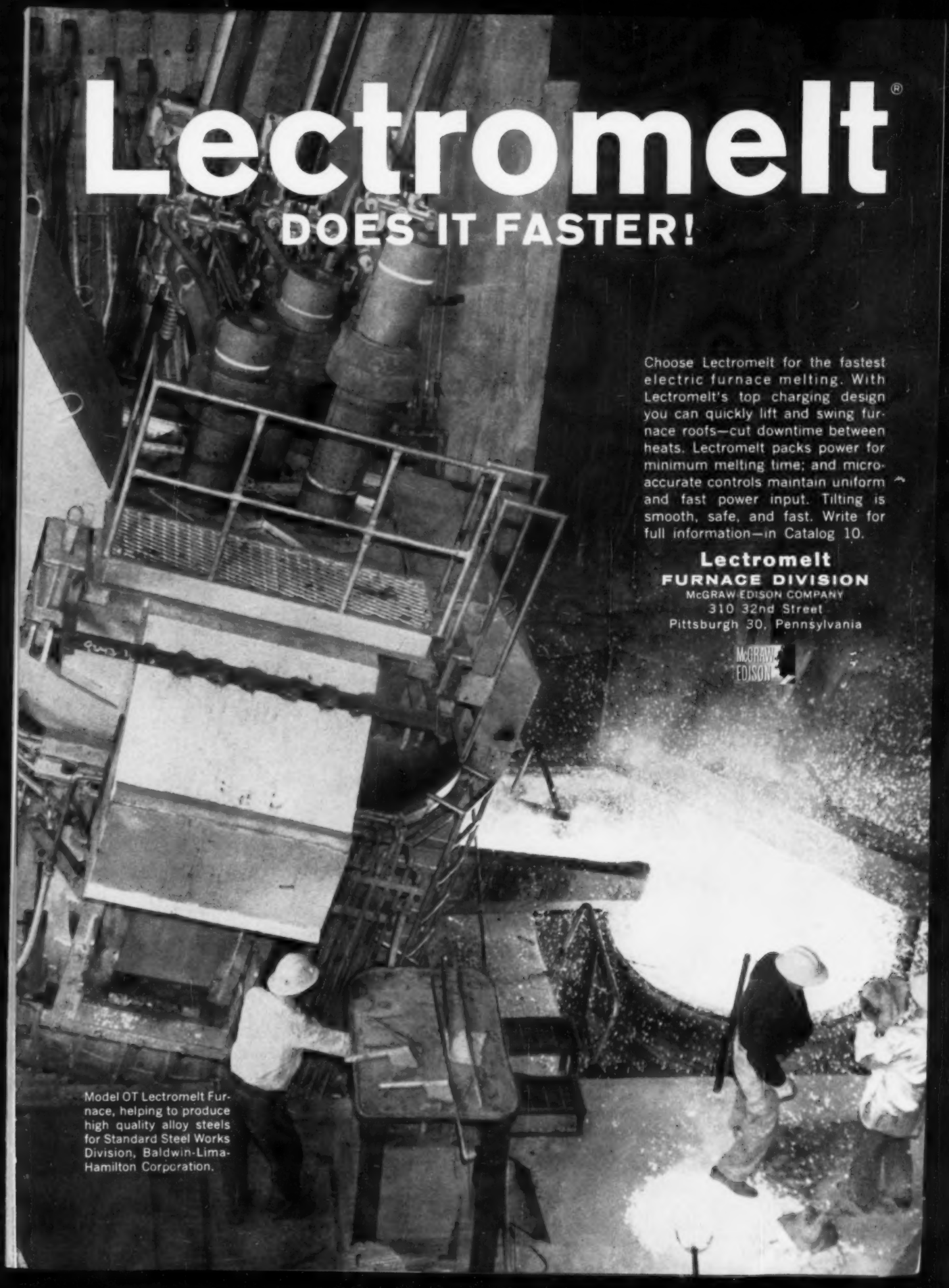
"Electromet" and "Union Carbide" are registered trade marks of Union Carbide Corporation.

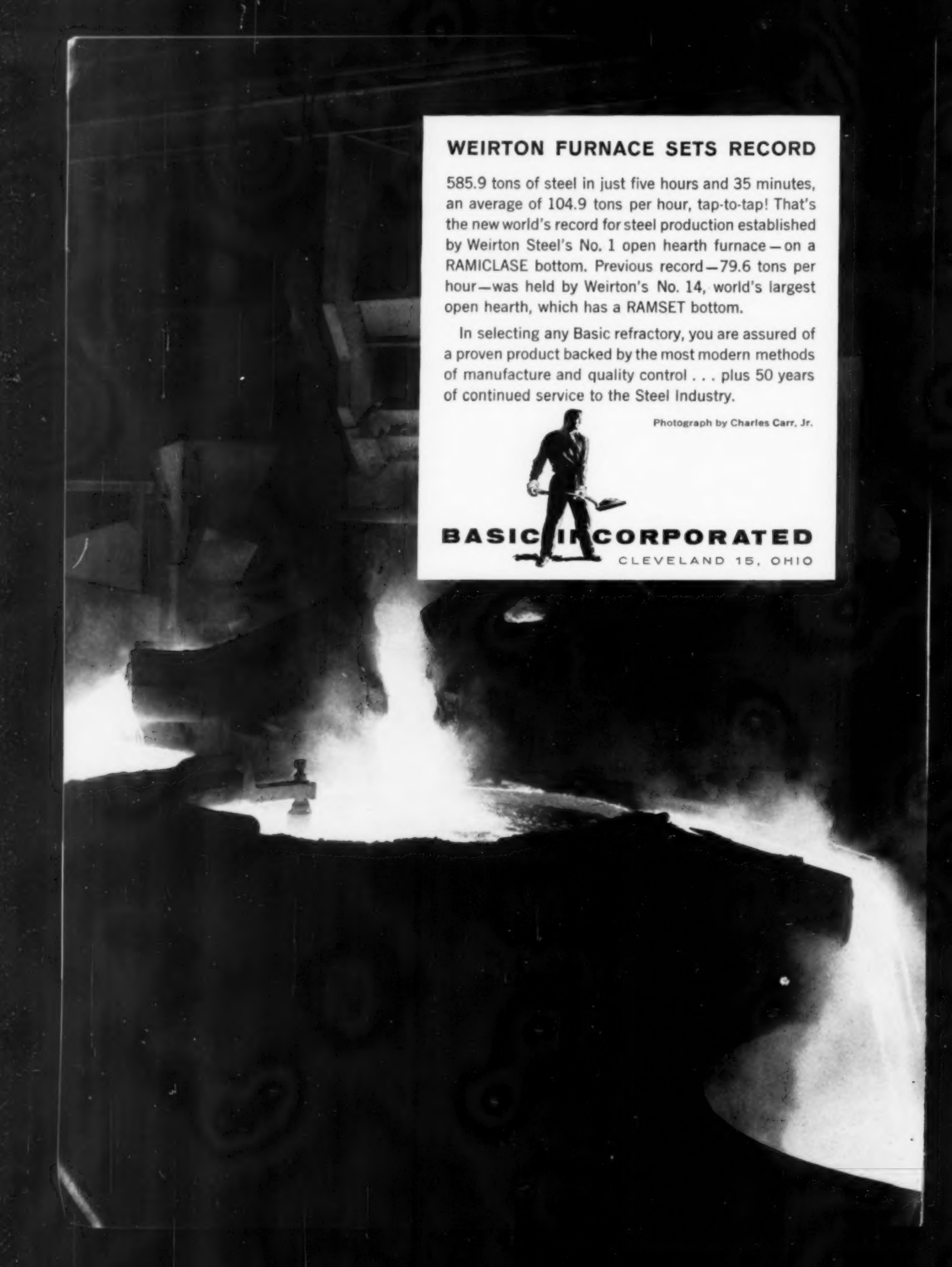


Not a single piece of scrap making up your shipment of secondary alloys from Frankel contains less than the amount of alloying agents you specify. This means that the average content of the alloying agents is to the maximum side of your specification.

That's your standard Frankel bonus. You pay nothing for it.

No wonder more and more buyers of secondary special alloys are turning to Frankel.


Lectromelt®
DOES IT FASTER!
Choose Lectromelt for the fastest electric furnace melting. With Lectromelt's top charging design you can quickly lift and swing furnace roofs—cut downtime between heats. Lectromelt packs power for minimum melting time; and micro-accurate controls maintain uniform and fast power input. Tilting is smooth, safe, and fast. Write for full information—in Catalog 10.
Lectromelt
FURNACE DIVISION
McGRAW-EDISON COMPANY
310 32nd Street
Pittsburgh 30, Pennsylvania
McGRAW EDISON
Model OT Lectromelt Furnace, helping to produce high quality alloy steels for Standard Steel Works Division, Baldwin-Lima-Hamilton Corporation.



WEIRTON FURNACE SETS RECORD

585.9 tons of steel in just five hours and 35 minutes, an average of 104.9 tons per hour, tap-to-tap! That's the new world's record for steel production established by Weirton Steel's No. 1 open hearth furnace—on a RAMICLASE bottom. Previous record—79.6 tons per hour—was held by Weirton's No. 14, world's largest open hearth, which has a RAMSET bottom.

In selecting any Basic refractory, you are assured of a proven product backed by the most modern methods of manufacture and quality control . . . plus 50 years of continued service to the Steel Industry.

Photograph by Charles Carr, Jr.

BASIC INCORPORATED

CLEVELAND 15, OHIO

Your best move is to UNITRON...

for a COMPLETE LINE of METALLURGICAL MICROSCOPES!

UNITRON'S Complete Line of Metallurgical Microscopes and Accessories covers the needs of Research, Industry and Education.

Quality optics . . . advanced optical and mechanical design . . . unique and convenient operational features . . . budget prices . . . free trial period — these, together with proven performance are the reasons why . . .

THE TREND IS TO UNITRON!

UNITRON

INSTRUMENT DIVISION OF UNITED SCIENTIFIC CO.
204-206 MILK STREET • BOSTON 9, MASSACHUSETTS

Please rush UNITRON's Microscope Catalog 10P-1.

Name_____

Company_____

Address_____

City_____ State_____

Education

(*Continued from page 227*)

ena, and facilitate the exchange of ideas and experience of various research groups. Contributions in the form of papers which may contribute to an understanding of the mechanism of sintering are solicited. For information, write to *G. C. Kuczynski, Professor of Metallurgy, P. O. Box 145, Notre Dame, Ind.*

EXPANSION

► **Case Institute of Technology** has appointed Dr. Paul Lacombe to the Republic Steel Corp. Chair of Metallurgy. Dr. Lacombe is head of the Dept. of Metallurgy and director of the research center at the School of Mines of Paris. He will teach on the graduate level.

► **New Mexico Institute of Mining and Technology's** board of regents has authorized the request for a new minerals industry building. One section will contain the metallurgical, petroleum, and mining engineering departments; another section will provide facilities for ore testing and research on ores now considered too low grade for commercial use.

► **The University of Rochester** has appointed its first dean of the College of Engineering. Dr. John W. Graham, Jr., currently vice president of The Cooper Union for the Advancement of Science and Art, will assume his duties on July 1st.

RESEARCH & WRITING

► **The National Science Foundation** has announced the award of 56 grants totaling approximately $800,000 to 54 educational institutions for the purpose of conducting programs in research participation for teacher training in the summer of 1959. Teachers will be chosen by the individual universities and colleges according to their qualifications in such a way that the research activity

(*Continued on page 292*)

PHYSICAL METALLURGISTS

Expanding programs at the Armour Research Foundation require the services of experienced physical metallurgists. Prefer personnel with an advanced degree, but will consider B.S. degree personnel with proven record of accomplishment. Challenging problems will enable you to contribute to the full extent of your ability.

Technical areas of current interest include:

Phase Diagrams
Solid Solution Strengthening
Solidification Studies
Transformation Kinetics
Dispersed Phase Activities
High-Temperature Alloys
Mechanisms of Fracture
Stress Corrosion
Fiber Metallurgy

If you have research experience in the above technical areas, write to:

A. J. Panerai
ARMOUR RESEARCH FOUNDATION
of Illinois Institute of Technology
10 West 35th St. Chicago 16, Ill.

INGOT MOULDS AND STOOLS

Valley Mould and Iron Corporation

Hubbard, Ohio

●

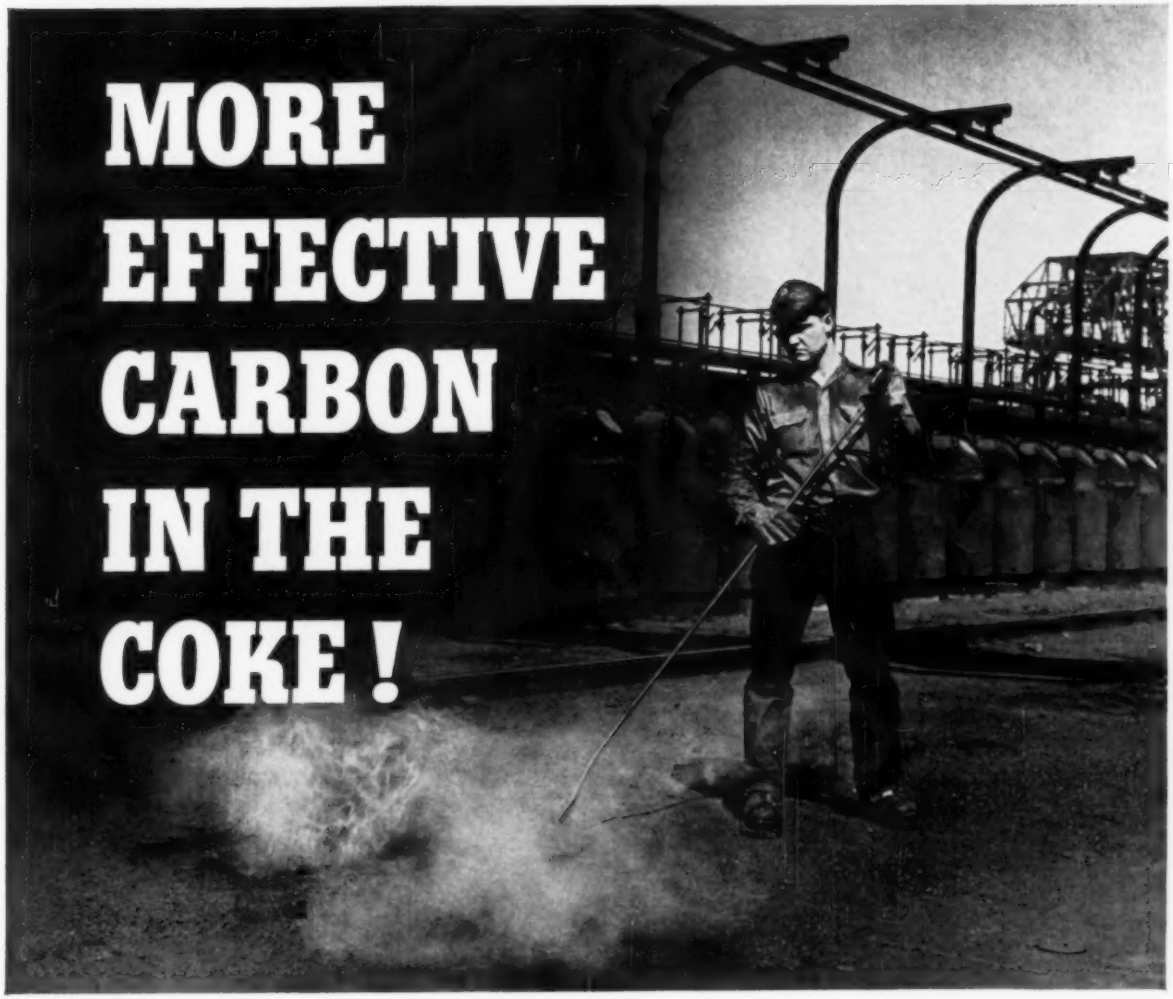
Works:

Chicago, Ill.

Cleveland, Ohio

Hubbard, Ohio

What feature of coking coal is the key to record-breaking performance?



Steel men know that part of the carbon in coke goes to take care of the ash and sulphur . . . and only what's left is truly *effective* carbon . . . actually available to produce hot metal. They know that this effective carbon is one of the truest measures of coke value . . . the *key* to lower coke rates and higher production rates.

To get high effective carbon, you have to start with a superior coking coal—low in ash and sulphur, high in coking properties.

Coke from Island Creek coking coals is consistently higher in effective carbon . . . often as much as 10% to 20% higher. Hardly surprising when you consider that these coals come from some of America's finest seams . . . and get superior preparation to meet your exact specifications.

Results? Less slag volume, lower coke rate, more production capacity per unit, lower coal cost per ton of hot metal.

Want the full story from our coking coal specialists? Just phone or wire at our expense.

You can depend on Coking Coals from

ISLAND CREEK

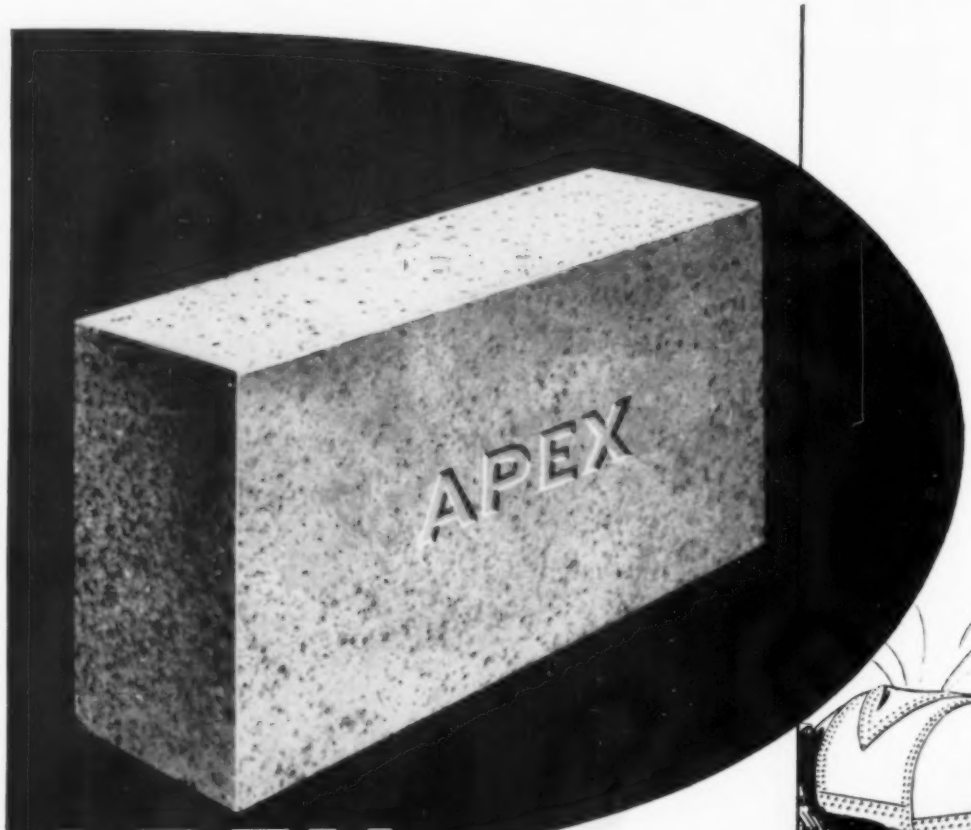
. . . a career company . . . dedicated to coal

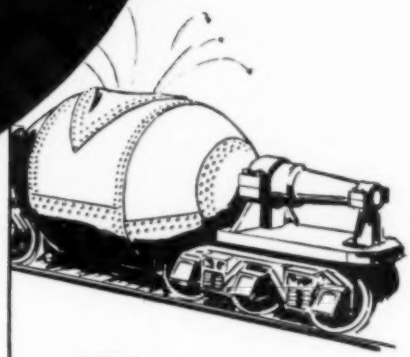
ISLAND CREEK COAL SALES COMPANY, Chafin Building, Huntington 18, West Virginia • Chicago • Cincinnati • Cleveland • Detroit • Greensboro • New York • Pittsburgh

Profit from the Higher Bulk Density of

WALSH APEX FIRE BRICK

WEIGH IN EXCESS OF 150 LBS. PER CUBIC FOOT





APEX SUPER DUTY FIRE BRICK

Apex, Super Duty Fire Brick Gives You More Fire Clay In Its Densest, Most Compact Form To Increase:

1. Resistance to wear
2. Heat storage and heat flow
3. Hot load bearing strength
4. Resistance to slag penetration

USES:

For record tonnage in Closed Hot Metal Torpedo Type Ladles, Hot Metal Mixers, and for maximum service and heat exchange in Hot Blast Stove Checkers and Open Hearth Checkers.

WALSH REFRACTORIES CORPORATION

101 FERRY STREET • ST. LOUIS 7, MISSOURI

SPECIALISTS IN REFRACTORIES OF HIGH BULK DENSITY AND LOW POROSITY

EDITORIAL

. . . . A Word to Authors of Technical Papers

by Robert Maddin, Chairman
Publications Committee of The Metallurgical Society

> " . . . . contributions of both practical and theoretical interest which treat significant advances in the science and engineering of metallurgy."

With these words, the Publications Committee of The Metallurgical Society set the broad limits for publication of papers in the TRANSACTIONS. Note particularly the word *engineering*—it is the desire of the Committee to emphasize the fact that the pages of TRANSACTIONS are open to papers of an engineering nature. The review committees are being scrutinized to assure that papers of appropriate quality will be accepted.

It is obvious that the word *engineering* above refers to all of the divisions of the Society, ISD, EMD, and IMD. It is strongly felt that the TRANSACTIONS, as a publication of the Society as a whole, must publish articles that are of permanent value to the metallurgical profession as a whole. As we all know, this represents a broad spectrum of interests. No one can claim that material of "permanent" value issues only from the fundamental science of metallurgy. It is our hope that during the coming year, more and more papers from EMD and ISD will be submittted to the TRANSACTIONS.

The same holds true for JOURNAL OF METALS. This magazine is dedicated, in part, to include ". . . articles describing new metallurgical plants and processes and (to) be concerned with the problems and advances in the application and utilization of metals." Whereas the prime concern in the TRANSACTIONS is the permanent value of a piece of work, the criterion for the JOURNAL OF METALS is that an article be of immediate interest to a significant portion of the Society's membership. Publication in the JOURNAL is entirely at the discretion of the Editor, who has the assistance of an advisory subcommittee. Here too, there is ample opportunity for publication from all portions of the Society.

Authors are invited to select which publication they feel their work should go into. As an alternative, they may submit their papers to the Editor of either journal, and solicit his advice as to whether a paper properly belongs in the JOURNAL or in the TRANSACTIONS. Papers intended for the TRANSACTIONS should be sent (3 copies) to Dr. G. Derge, Editor, TRANSACTIONS OF THE METALLURGICAL SOCIETY, Carnegie Institute of Technology, Schenley Park, Pittsburgh 13, Pa. Papers for the JOURNAL should be directed to Mr. F. Weston Starratt, JOURNAL OF METALS, 29 W. 39th Street, New York 18, N. Y. In any event, both editors will make every effort to assure publication of all worthy papers in the appropriate journal.

THE METALLURGICAL SOCIETY OF AIME

John Chipman, President
W. R. Hibbard, Jr., Past-President
C. C. Long, Vice President
T. D. Jones, Treasurer
R. W. Shearman, Secretary

BOARD OF DIRECTORS, THE METALLURGICAL SOCIETY

J. B. Austin, H. B. Emerick, R. W. Farley, J. H. Hollomon, H. H. Kellogg, A. E. Lee, Jr., O. T. Marzke, K. C. McCutcheon, R. R. McNaughton, J. S. Smart, Jr., J. D. Sullivan, M. Tenenbaum

DIVISION PUBLICATIONS COMMITTEE CHAIRMEN

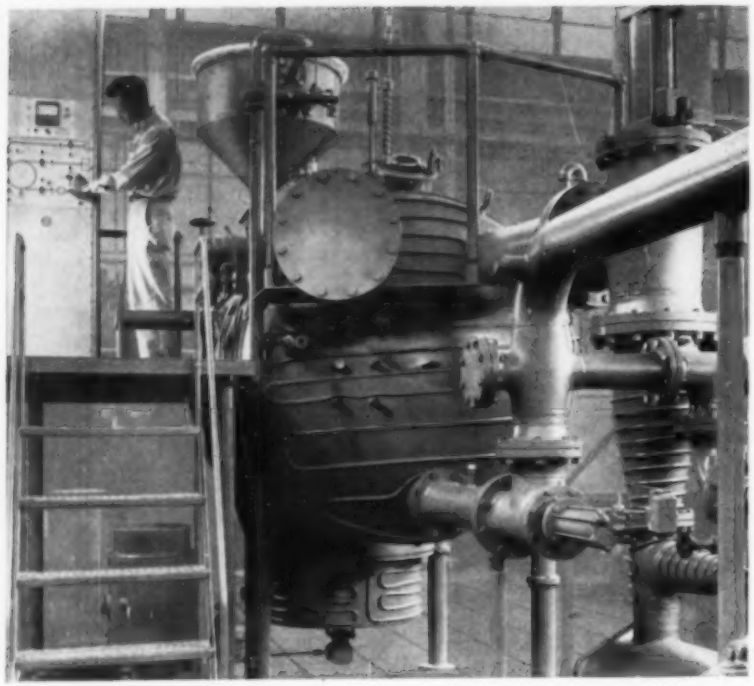
T. B. King, Extractive Metallurgy
W. O. Philbrook, Iron and Steel
F. L. Vogel, Institute of Metals

SOCIETY PUBLICATIONS COMMITTEE

R. Maddin, Chairman
Denis Carney, C. C. Long
J. C. Fulton, W. O. Philbrook
J. H. Hollomon, J. D. Sullivan
T. B. King, David Swan
F. L. Vogel

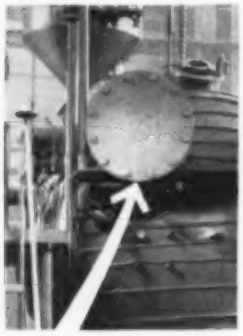
Advisory Subcommittee

J. H. Hollomon, Chairman
D. Carney, E. Morgan
J. F. Elliott, T. O. Paine
B. W. Gonser, A. Shaler
J. D. Hanawalt, V. Zackay
J. H. Jackson, J. R. Freeman, Jr.
A. E. Lee, Jr., J. Harwood
T. Read



Get started in vacuum metallurgy this sensible pay-as-you-grow way

You may never need more than the basic 50-to-200 lb. capacity of the CEC vacuum induction furnace shown above. It's ample for medium-scale melting and casting. But if your needs change, as they well may in this rapidly expanding field, you can easily increase capacity to 300 lbs. Just open the flanged nozzle (arrow, left) and add another pumping system. Similarly, with the CEC laboratory and pilot plant model, you can start out with 5 lb. melts, then only change crucibles to accommodate 12, 17, 30, even production-rate 50-lb. melts. Same with the big CEC large-scale production model . . . it's expandable from 300 to 1000 lbs. The capacity is there, if you want it. You pay only for what you need, when you need it.



CEC gives you room to grow

WRITE for informative Bulletins P4-30, 32.

Consolidated Electrodynamics

Rochester Division, Rochester 3, N.Y.

SALES AND SERVICE OFFICES IN PRINCIPAL CITIES

Physical Metallurgist
Ceramist
Solid State Chemist

The Office of Naval Research, as the central research organization of the Navy Department, sponsors broad programs of basic and applied scientific research in university and other laboratories. The services of outstanding research scientists are employed to plan, organize, and direct major contract research programs in their fields.

The Metallurgy Branch of the Office of Naval Research offers excellent opportunities for qualified research scientists in the fields indicated below. Salaries range from $10,130 to $12,770 depending upon qualifications.

PHYSICAL METALLURGIST

(Solid State emphasis)—Imperfections in solids, physics of metals, deformation and fracture phase transformations, chemistry and physics of surfaces and interfaces.

CERAMIST or SOLID STATE CHEMIST

Ceramics and inorganic nonmetallic solids including defect structure and structure-sensitive properties, solid-state reactions, mechanical behavior; semi-conducting materials for energy conversion systems; ferroelectric, dielectric, ferromagnetic and special materials.

These positions are for duty in Washington, D.C., and will be filled in accordance with applicable civil service procedures. University scientists on sabbatical leave considered.

Applicants are invited to send their qualifications and inquiries to Director, Civilian Personnel and Services Division.

ONR

Office of Naval Research

Room 1070, T-3 Bldg.,
17th & Constitution
Washington 25, D.C.

Meet Me In St. Louis....

Symbolic Of The Steel Industry
is this open-hearth furnace being charged with hot metal from the blast furnace. This month in St. Louis (April 6-8), over 1,500 metals men who are professionally involved in open-hearth and blast-furnace operations are attending the conferences of the AIME National Open Hearth Steel and Blast Furnace, Coke Oven, and Raw Materials Committees.

METALLURGICAL SOCIETY OF AIME
AI ME

Identifying Modern Steel Men
as professional metals men is the seal of The Metallurgical Society of AIME. Such men count on the services of the Iron and Steel Division of the Society to help them in their professional and personal development. Society services include such well established meetings as the Open Hearth and Blast Furnace Conferences as well as a variety of other gatherings and publications in response to members' needs.

The Metallurgical Society
of AIME serves metals men engaged in extracting, refining, and fabricating metals, in metallurgical research, and in the development and application of metals and alloys. More than 7,000 members insure their own development while discharging their professional obligation by supporting the organization that fosters their best interests. Use the coupon at the right to learn more about The Metallurgical Society.

The Metallurgical Society of AIME
29 West 39th Street
New York 18, New York

Gentlemen:

I am interested in joining the Society. Please send further information and an application for membership.

Name _____

Address _____

_____

_____

TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME

Contents of the April, 1959, issue

The Thermodynamics of the Liquidus-Solidus Gap in Binary Alloys: The Silver-Gold System
J. L. White 178

The Activities of Iron and Nickel in Liquid Fe-Ni Alloys
G. R. Zellars, S. L. Payne, J. P. Morris, and R. L. Kipp 181

Activities of Iron and Nickel in Liquid Iron-Nickel Solutions
R. Speiser, A. J. Jacobs, and J. W. Spretnak 185

The Lanthanum-Carbon System
F. H. Spedding, K. Gschneider, Jr., and A. H. Daane 192

The Antimony-Uranium Alloy System
B. J. Beaudry and A. H. Daane 199

Creep Deformation of Aluminum-Copper Two-Phase Alloys
R. M. N. Pelloux, A. R. Chaudhuri, and N. J. Grant 204

The Dislocation-Oxygen Interaction in Alpha Titanium and Its Effect on the Ductile-to-Brittle Transition
D. Gupta and S. Weinig 209

A Search for the Sigma Phase in the Fe-W and Co-W Alloy Systems
E. C. van Reuth 216

The Free-Energy Changes Attending the Martensitic Transformation in the Iron-Chromium and Iron-Chromium-Nickel Systems
Larry Kaufman 218

The Nature of the β, β_1 and β'' Phases in the Cu-Al System
D. F. Toner 223

Dislocation Blocking in Face-Centered-Cubic Metals
I. R. Kramer 226

Cause of Cleavage Fracture in Ductile Materials
J. Washburn, A. E. Gorum, and E. R. Parker 230

Heat Treatment, Transformation Reactions, and Mechanical Properties of Some High-Strength Zirconium-Base Alloys
H. A. Robinson, J. R. Doig, M. W. Mote, and P. D. Frost 237

The Irradiation Stability of Low Wt Pct Uranium-Zirconium Alloys
A. H. Willis 245

Cold-Rolling Textures of Iron-Base Alloys Containing 3 to 12 Pct Aluminum
R. G. Aspden, J. A. Berger, and R. S. Mateer 251

Electrodeposition of Titanium from Fused Chloride Baths Using TiCl, As a Feed Material
W. R. Opie and K. A. Svanstrom 253

On the Nickel-Rich End of the Zirconium-Nickel Phase Diagram:
D. Kramer 256

Freezing of Liquid Metal in a Mold:
G. Horvay and J. G. Henzel 258

X-Ray Detection of Dislocation Tilts and Strains in Single Crystals of Copper:
Larry Kaufman and S. Andrew Kulin 273

Diffusion of Zinc from the Vapor Phase into Copper-Zinc and Silver-Zinc Alloys:
A. G. Guy 279

CsCl-Type Equiatomic Phases in Binary Alloys of Transition Elements:
A. E. Dwight 283

Orientation Sensibility of Alpha Titanium to Electrostraining:
R. H. Hiltz and R. W. Douglass 286

Retrogession in Age Hardening:
L. F. Mondolfo 289

A Proposed Mechanism for the Strengthening of SAP-Type Alloys:
G. S. Ansell 294

The Effect of Surface Adsorption of Gas on Crack Propagation: M. R. Achter and H. W. Fox 295

Preparation of Two Lithium-Arsenic Compounds: R. E. Tate and F. W. Schonfeld 296

Solubility of Oxygen in Alpha Iron: A Revision: A. U. Seybolt 298

A Study of the Peritectoid Transformation: R. D. Reiswig and D. J. Mack 301

A New Etchant for Zinc Alloys: R. J. Gennone and E. C. Kersey 307

Porosity in Formed Titanium:
R. A. Wood, D. N. Williams, H. R. Ogden, and R. I. Jaffee 308

Activation Energies for Creep of Single Aluminum Crystals Favorably Oriented for Cubic Slip:
Y. A. Rocher, L. A. Shepard, and J. E. Dorn 316

Observation on the Recrystallization of a Silicon-Iron Crystal in a Polygonized Matrix:
Hsun Hu 320

An Investigation of the Effects of Variables on the Stored Energy of Cold Work:
A. L. Tichener and M. B. Bever 326

The Immiscibility Limits of Uranium with the Rare-Earth Metals: J. F. Haefling and A. H. Daane 336

Diffusion of Bismuth in Copper Grain Boundaries: S. Yukawa and M. J. Sinott 338

Strengthening of Copper Alloys by Internal Oxidation: M. Safdar Ali and V. A. Phillips 340

Nonmetallic Dispersions in Cobalt: E. F. Adkins, C. T. Sims, and R. I. Jaffee 344

METALLURGICAL SOCIETY OFFICERS

(President John Chipman's biography appeared in the February 1959 issue.)

Past-President

Walter R. Hibbard, Jr.

Dr. Hibbard, manager, alloys studies research, General Electric research laboratory, Schenectady, is the author of more than 60 papers on physical metallurgy. Joining AIME in 1940, Dr. Hibbard participated actively in the Institute, serving as Chairman of the IMD in 1957, and as a member of the Programs Committee, the Mathewson Gold Medal Committee, the Publications Committee, and the Executive Committee. He is the 1950 winner of the *Rossiter W. Raymond Award*. A native of Bridgeport, Conn., he graduated from Wesleyan University in 1939 and from Yale University (doctorate in physical metallurgy) in 1942. After three years with the metallurgical section of the Bureau of Ships, USN, he returned to Yale as assistant professor, later becoming an associate professor. Dr. Hibbard joined the staff at General Electric in 1951.

Vice President

Carlton C. Long

Dr. Long, director of research, Zinc Smelting div., St. Joseph Lead Co., became a member of AIME in 1937. He has held numerous positions in the Society including Chairman of the Lead-Zinc Committee, Chairman of the Douglas Award Committee, Chairman of EMD (and one of its founders), Metals Branch Chairman, and Director of AIME. Dr. Long has participated in the affairs of a broad range of professional and technical societies. His professional publications have dealt principally with electrothermic zinc and the development of young engineers. He received his doctorate at Stanford University and moved to the east coast in 1935 when he joined the technical staff of Josephtown Smelter.

Treasurer

T. D. Jones

Mr. Jones, beginning his second year as treasurer of The Metallurgical Society, has been associated with American Smelting & Refining Co. since 1922. A member of AIME for 28 years, he has played a major role in EMD, serving as Chairman of that group in 1952. He has also sat on the EMD Executive Committee, the all-Institute Admissions Committee, and the National Steering Committee. Mr. Jones received a professional degree of metallurgical engineer in 1929 from the University of Wisconsin.

DIRECTORS FROM EXTRACTIVE METALLURGY DIVISION

Herbert H. Kellogg

Dr. Kellogg ('60)* is professor of mineral engineering, Columbia University School of Mines. Prof. Kellogg has been active in the affairs of EMD since its formation in 1950. He fathered the Committee on Physical Chemistry of Extractive Metallurgy and was its Chairman from 1950 to 1952. A former Chairman of the Papers and Programs Committee, and the Electrolytic Extractive Processes Committee, he was Chairman of EMD last year. He is the author of numerous technical articles, and is connected closely with titanium development.

Ronald R. McNaughton

Mr. McNaughton ('61)*, manager, Metallurgical div., The Consolidated Mining & Smelting Co. of Canada Ltd., served as Chairman of EMD in 1953. During the same year and the one following, he was a Director of AIME. In the course of 35 years with Consolidated, he has held positions in the Smelting dept. as assistant foreman, development engineer, assistant superintendent, and metallurgist. Following a term as chief metallurgist, he was appointed manager of the Metallurgical div. in 1946.

John D. Sullivan

Mr. Sullivan ('62)*, technical director at Battelle Memorial Institute, is a former Chairman of the Douglas Award Committee. An active member of AIME since 1930, he was one of the founders of EMD, acting as its first Chairman from 1948 to 1950. He has been a member of the Executive Committee and the Publications Committee of EMD since its inception. Mr. Sullivan also has served on the Executive Committee of IMD. He has published more than 100 articles in the areas of metallurgy, chemistry, and ceramics.

DIRECTORS FROM INSTITUTE OF METALS DIVISION

James B. Austin

Dr. Austin ('60)* is vice president, research and technology, U. S. Steel Corp. As a member of AIME since 1944, he has made important contributions in the publications area, and has served on the IMD Executive Committee. A native of Washington, D. C., Dr. Austin received his Ph.D. in physical chemistry from Yale and joined U. S. Steel in 1928. He has remained with the corporation for 31 years, assuming his present position in 1956. His activities as a member of the American Society for Metals include a term as president in 1953.

J. S. Smart, Jr.

Mr. Smart ('61)* gained his early experience with the Ford Motor Co. and Detroit Lubricator Co. before affiliating with the American Smelting & Refining Co. as a research metallurgist in 1936. He assumed his present position as general sales manager last year. While in the research department, his principal interests were in the field of copper metallurgy and continuous casting. Mr. Smart was a Director of AIME in 1955, Chairman of the Rossiter W. Raymond Award Committee in 1954, and the recipient of the *IMD Award* (now the *Mathewson Gold Medal*).

John H. Hollomon

Dr. Hollomon ('62)*, manager of metallurgy and ceramics research dept., General Electric research laboratories, joined AIME in 1944. In 1958 he was a member of The Metallurgical Society Publications Committee, Metallurgical Profession Committee, JOURNAL OF METALS Advisory Subcommittee, TRANSACTIONS Advisory Subcommittee, IMD Executive Committee, and Annual Lecture Committee. He has authored or co-authored some 40 papers in journals of physics and metallurgy, as well as a textbook on ferrous metallurgical design.

* Year of expiration of term.

DIRECTORS FROM IRON AND STEEL DIVISION

K. C. McCutcheon

Mr. McCutcheon ('60)*, consultant to Armco Steel Corp., has been associated with the steel industry for 42 years. He worked with the Carnegie Steel Co. in Duquesne, Pa., until 1922 when he joined Armco at Ashland, Ky., as assistant superintendent, open hearths, eventually becoming assistant to the vice president, planning and development. Mr. McCutcheon was an AIME Director in 1952 and 1953, Chairman of ISD in 1952, recipient of the *Robert W. Hunt Medal* in 1939, and Chairman of the Fairless Award Committee in 1955.

Harold B. Emerick

Mr. Emerick ('61)* became a member of AIME in 1943, served as Chairman of ISD in 1957, and was a co-recipient of the *Frank B. McKune Memorial Award* of AIME in 1942. He is director of technical services, Jones & Laughlin Steel Corp. Author or coauthor of some 15 published articles, he is the co-editor of *Basic Open Hearth Steelmaking*, published by AIME in 1951. Mr. Emerick studied at Carnegie Institute of Technology and the University of Pittsburgh. He joined J & L in 1935 as a metallurgical investigator.

Ralph W. Farley

Mr. Farley ('62)* is director of process development, Chicago district, Republic Steel Corp. An AIME member for 12 years, he has served on the ISD Electric Furnace Conference Committee and the Physical Chemistry of Steelmaking Committee. Mr. Farley received his degree in chemical engineering from the University of Michigan in 1932. Prior to joining Republic, he was employed as a chemist, laboratory assistant, plating foreman, and consultant. He is a member of ASM and API.

CHAIRMEN

IMD

Oscar T. Marzke

Dr. Marzke ('60)*, vice president, fundamental research, U. S. Steel Corp., has been a member of AIME for 27 years. One year after receiving his doctorate in metallurgy from Massachusetts Institute of Technology, he became affiliated with U. S. Steel at the American Steel & Wire's research laboratory in Worcester. Dr. Marzke is a member of several advisory committees, including the Materials Advisory Board of the National Academy of Sciences and the National Science Foundation.

ISD

Michael Tenenbaum

Dr. Tenenbaum ('60)* is asst. general manager, technical services, Inland Steel Co., East Chicago, Ind. An active member since 1940, he has received the *Rossiter W. Raymond Memorial Award* and the *Robert W. Hunt Award* (1949). During 1958 he was a member of the ISD Mechanical Working Committee, Open Hearth Steel Committee executive board, and the McKune Award Committee. Dr. Tenenbaum received his M.S. and Ph.D. degrees in metallurgical engineering from the University of Minnesota.

EMD

Albert E. Lee, Jr.

Mr. Lee ('60)* is manager, Zinc Operations, American Metal Climax Inc. He served as a procurement officer in the US Army's Philadelphia Ordnance District from 1941 until 1946, joining AMC in 1946. He transferred to the New York office from the Blackwell, Okla., zinc smelter in 1955.

During 1958, Mr. Lee was a member of The Metallurgical Society Publication Committee and the JOURNAL OF METALS Advisory Subcommittee, the EMD Papers and Programs Committee, and the Structure of Technical Committees.

PROGRAMS

Blast Furnace, Coke Oven, and Raw Materials Committee and National Open Hearth Steel Committee

The Jefferson Hotel, St. Louis, will be the scene of the 42nd Conference, held April 6-8, 1959. Registration will be in the Mezzanine, Jefferson Hotel, 3:00 to 9:00 pm, Sunday, April 5; 8:00 am to 5:00 pm, Monday and Tuesday, April 6 and 7; and 8:00 am to 4:00 pm, Wednesday, April 8. Special busses for the plant trips to Granite City Steel Co. and American Steel Foundries on Wednesday, April 8, will depart from Jefferson Hotel (12th Street Entrance) at 9:00 am.

National Open Hearth Steel Conference

MONDAY AND TUESDAY, APRIL 6 AND 7

8:00 am—Room #1

Authors and Chairmen Breakfasts

Authors and session chairmen of the day will meet for breakfast followed by an opportunity to plan final details with regard to the schedule of papers for each session on that day.

Annual Fellowship Dinner

Tuesday, April 7

6:30 pm—Ivory Room

Reception and Cocktail Party for dinner guests

7:00 pm—Gold Room

Annual Fellowship Dinner

Toastmaster: *Joseph Holland*, Special Assistant to Publisher, "St. Louis Post-Dispatch," St. Louis.

Speaker: *William McDonnell*, President, U. S. Chamber of Commerce, and Chairman of Board of First National Bank in St. Louis, St. Louis.

Entertainment at Fellowship Dinner

Immediately following the Banquet, the Southwestern Section, NOHC, will provide a brief program of light entertainment with refreshments and an attractive souvenir of the St. Louis meeting for all in attendance. Guests need not leave their tables; the musical program will be brief.

Monday, April 6

General Session

Welcoming Remarks: *V. W. Jones*, Assistant General Superintendent, Armco Steel Corp., and General Chairman, National Open Hearth Steel Committee, AIME

Announcements and Reports

McKune Award Paper

10:30 am to 12:15 pm—Gold Room

Basic Operations Session

Chairmen: *C. W. Conn*, Production Manager-Steel Division, Ford Motor Co., Dearborn, Mich., and *J. A. Glasgow*, Superintendent Open Hearth, Jones & Laughlin Steel Corp., Cleveland, Ohio.

Description of Sparrows Point #4 Open Hearth: *F. J. Broglie*, Assistant to Superintendent of Open Hearth and Bessemer, Bethlehem Steel Co., Sparrows Point, Md. and *G. L. Cox*, Sales Manager, Freyn Department, Koppers Co., Inc., Pittsburgh, Pa.

Open Hearth Problems With High Per Cent Hot Metal Charge: *Ralph Duffet*, Superintendent, Open Hearths and Bessemer, Great Lakes Steel Corp., Detroit, Mich.

10:30 am to 12:15 pm—Crystal Room

Acid Operations Session

Chairmen: *H. E. Klugh*, Foundry Superintendent, Mesta Machine Co., New Castle, Pa., and *J. B. Kopec*, Metallurgical Engineer, John A. Roebling's Sons Corp., Trenton, N. J.

Use of Pig Iron Substitutes: *L. W. Krum*, Plant Manager, Strong Steel Foundry Co., Buffalo, N. Y.

Use of Oxygen for Complete Refining: *R. M. Barnhart*, Open Hearth Superintendent, Alco Products Co., Latrobe, Pa.

Use of Deuterium as a Tracer Element for Hydrogen in Steel: *G. R. Fitterer*, Dean, Schools of Engineering and Mines, University of Pittsburgh, Pittsburgh, Pa., and *J. G. Bassett*, Research Engineer, Acid Open Hearth Research Association, Inc., Pittsburgh, Pa.

2:00 to 5:00 pm—Mirror Room, Third Floor, Bishop Tuttle Memorial*

Operating Metallurgy Session

Chairmen: *F. W. Luerssen*, Chief Research Engineer, Reduction and Refining Activities, Inland Steel Co., East Chicago, Ind., and *C. W. Hart*, Chief Metallurgist, Republic Steel Corp., Buffalo, N. Y.

Control of Chemical Composition: A Practical Program for the Control of Open Hearth Chemistry: *T. D. Hess*, Superintendent No. 1 Open Hearth, and *R. L. Kimberly*, Youngstown Steel and Tube Co., Indiana Harbor Works, East Chicago, Ind.

Discussion: *E. J. Whittenberger*, Assistant Superintendent of No. 4 Open Hearth, Gary Works, United States Steel Corp., Gary, Ind.

Use of Capped Low Carbon Steel Ingots for Drawing Quality Cold Rolled Sheet Applications:

(a) Chemically Capped Ingots: *J. S. McNairn*, Supervisor, Quality Control, Ford Motor Co., Dearborn, Mich.

Discussion: *E. W. Mahaney*, Assistant Superintendent Metallurgy, Youngstown Sheet and Tube Co., Indiana Harbor Works, East Chicago, Ind., and *W. P. Connor*, Steel Works, Metallurgist, Jones & Laughlin Steel Corp., Cleveland, Ohio.

(b) Mechanically Capped Ingots: *V. H. Bridgewood*, Division Metallurgist, and *J. F. Jarrell*, Steel Co. of Canada, Ltd., Hamilton, Ont., Canada

Discussion: *W. H. Mayo*, Manager, Process Control Metallurgy, United States Steel Corp., Pittsburgh, Pa.

(c) Large Rimmed Ingots: *Harold Farling*, Chief Metallurgist, Republic Steel Corp., Cleveland, Ohio

Steel Cleanliness:

(a) A Study of the influence of Bath Deoxidation on the Cleanliness of 1030 Steel: *K. R. Mattson*, Assistant Superintendent Metallurgical Department, Inland Steel Co., East Chicago, Ind.

(b) Review of Symposium on Quality Requirements of Super-Duty Steels: *J. F. Elliott*, Associate Professor of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

*Rear of Christ Church Cathedral. Entrance is across Locust Street from South Entrance of Sheraton-Jefferson Hotel.

2:00 to 5:00 pm—Gold Room

Refractories Session (I)

Chairmen: *T. G. Harkins*, Open Hearth Superintendent, Crucible Steel Co. of America, Midland, Pa., and *F. A. Colledge*, Superintendent Masonry, United States Steel Corp., Munhall, Pa.

Properties and Composition of the Various Types of Basic Brick on Roofs: *W. S. Debenham*, Chief Research Engineer, United States Steel Corp., Pittsburgh, Pa.

Design and Operating Performance of Basic Sprung Roofs: *H. A. Parker*, Division Superintendent Steel Production, United States Steel Corporation, Fairless Hills, Pa.

Problems Encountered With Other Section of Basic Roof Furnaces: *W. J. Scharfenaker*, Chief Ceramic Engineer, National Steel Corp., Pittsburgh, Pa.

Discussion: *J. F. Pollack*, Superintendent Open Hearth Department, Jones & Laughlin Steel Corp., Pittsburgh, Pa., *F. R. Smith, Jr.*, Division Superintendent, Steel Production, United States Steel Corp., Gary, Ind., *P. W. Nutting*, Assistant Superintendent #2 Open Hearth, Indiana Harbor Works, Inland Steel Co., East Chicago, Ind., and *J. J. Hazel*, Ceramic Engineer, Metallurgical Department, Republic Steel Corp., Cleveland, Ohio

Tuesday, April 7

9:30 am to 12:15 pm—Gold Room

Refractories Session (II)

Chairmen: *R. G. Phelps*, Manager, Steel Production, Inland Steel Co., East Chicago, Ind., and *S. M. Purcell*, Superintendent Open Hearth, Lone Star Steel Co., Lone Star, Texas

Evaluation of Clinkered Dolomite Material: *A. Sontz*, Ceramic Engineer—Development, and *R. N. Ames*, General Supervisor, Ceramic Development, South Works, United States Steel Corp., Chicago, Ill.

Gun Emplaced Silicia Ganister in the Open Hearth: *J. V. Grothaus*, Plant Ceramic Engineer, Great Lakes Steel Corp., Detroit, Mich.

Improved Methods of Repairing Open Hearth Furnace Roofs: *A. J. Voss*, Superintendent, Masonry Department, Inland Steel Co., East Chicago, Ind.

Basic Open Hearth Checkers: *W. W. Bergmann*, Superintendent No. 1 Open Hearth, Armco Steel Corp., Middletown, Ohio

9:30 am to 12:15 pm—Crystal Room

Operating and Combustion Session

Chairmen: *A. K. Moore*, Superintendent Open Hearths, Steel Co. of Canada, Ltd., Hamilton, Ont., Canada, and *O. W. Morris*, Combustion Engineer, Armco Steel Corp., Ashland, Ky.

New Process for Bottom Blowing With High Pressure Oxygen: *Guy Savard*, Former Manager Technical Development Department, *Robert Lee*, Metallurgist, Technical Development Department, Canadian Liquid Air Co., Ltd., Div. of L'Air Liquide, Montreal, Que., Canada, and *M. R. Campbell*, Assistant General Superintendent, Dominion Iron and Steel Corp., Sydney, N. S., Canada

Fuel Practice at Fontana: *H. I. Riegel*, Superintendent Utilities, Kaiser Steel Corp., Fontana, Calif.

International Flame Radiation Committee Studies: *F. W. Luerssen*, Chief Research Engineer, Reduction and Refining Activities, Inland Steel Co., East Chicago, Ind.

2:00 to 5:00 pm—Gold Room

Oxygen Steelmaking Processes Session

Chairmen: *C. M. Kay*, Assistant Chairman, Operating Committee, United States Steel Corp., Pittsburgh, Pa., and *D. W. Murphy*, Technical Adviser, Bethlehem Steel Co., Bethlehem, Pa.

Use of Oxygen in Steelmaking: *T. B. King*, Assistant Professor, Massachusetts Institute of Technology, Cambridge, Mass.

Effect of Oxygen on Open Hearth Production: *J. L. Evans*, General Foreman, Open Hearth, Dept. Wheeling Steel Corp., Wheeling, W. Va.

Oxygen Steelmaking Processes: *D. R. Loughrey*, Coordinator of Steelmaking, Jones & Laughlin Steel Corp., Pittsburgh, Pa., *William Bower*, Superintendent Steel Production, Kaiser Steel Corp., Fontana, Calif., *C. J. Petry*, Acme Steel Co., Chicago, Ill., *J. R. Atkinson*, Superintendent of Melting, Dominion Foundries and Steel Ltd., Hamilton, Ont., Canada, and *C. C. Benton*, Division Superintendent, Algoma Steel Corp., Ltd., Sault Ste. Marie, Ont., Canada

2:00 to 5:00 pm—Crystal Room

Cold Metal and Basic Foundry Session

Chairmen: *R. R. Fayles*, Manager of Steel Plants, Lukens Steel Co., Coatesville, Pa., and *S. L. Fredericks*, Assistant to Works Manager, American Steel Foundries, Granite City, Ill.

Use of Prolerized Scrap: *W. F. Mott*, Superintendent Steel Production, and *G. W. Brooks*, Works Metallurgist, Armco Steel Corp., Houston, Texas

Use of Calderon Charger: *H. M. Parker*, Superintendent of Melting, Armco Steel Corp., Butler, Pa.

Use of Oxygen in Cold Metal Shops: *G. S. Baldwin*, Open Hearth Superintendent, Standard Steel Works Div., Baldwin-Lima-Hamilton Corp., Burnham, Pa.

Use of Iron Substitutes: *H. W. Potter*, Assistant Superintendent of Melting, Lukens Steel Co., Coatesville, Pa.

Blast Furnace, Coke Oven, and Raw Materials Conference

MONDAY AND TUESDAY, APRIL 6 AND 7

8:00 am—Room #1

Authors and Chairmen Breakfasts

Authors and session chairmen of the day will meet for breakfast followed by an opportunity to plan final details with regard to the schedule of papers for each session on that day.

Annual Luncheon and Business Meeting, Blast Furnace, Coke Oven, and Raw Materials Committee

Tuesday, April 7

12:30 pm—Ivory Room

J. W. Duncan, Chairman

Everyone attending the Blast Furnace, Coke Oven, and Raw Materials Conference is invited to attend this luncheon and annual business meeting.

(Tickets $3.50, tips and tax included; see page 4)

9:30 am to 12:15 pm—Room #1

Coal Session

Chairmen: *P. L. Richards*, Manager Coal Preparation, United States Steel Corp., Pittsburgh, Pa., and *Charles Potter*, Supervisor of Raw Materials Services, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

Automatic Sampling and Bulk Density Control of Coking Blends: Preprinted paper by *Samuel Prellwitz*, Development Metallurgist, Fairless Works, United States Steel Corp., Fairless Hills, Pa.

Coal Grinding Panel Session: Moderator: *A. H. Brisse*, Chief Research Engineer, Coal and Coke, United States Steel Corp., Pittsburgh, Pa.
Introduction: *B. R. Kuchta*, Junior Technologist, Applied Research Laboratory, United States Steel Corp., Monroeville, Pa.

M. B. Mairs, Manager, Mineral Dressing Equipment Mining and Construction Div., Joy Manufacturing Co., Pittsburgh, Pa.

C. W. Stahl, Bethlehem Steel Co., Bethlehem, Pa.
J. J. Bradfield, Sales Engineer, Pennsylvania Crusher Co., Bath Iron Works Corp., West Chester, Pa.
J. C. P. Taylor, Manager, Pulverizer and Crusher Sales, Jeffrey Manufacturing Co., Columbus, Ohio.

9:30 am to 12:15 pm—Ivory Room

Raw Materials and Miscellaneous Session

Chairmen: *F. C. Anderko*, Assistant to Division Superintendent, Blast Furnaces, Bethlehem Steel Co., Bethlehem, Pa., and *R. L. Stephenson*, Chief Research Engineer, Raw Materials and Ore Reduction, United States Steel Corp., Monroeville, Pa.

Ore Handling and Beneficiation at Great Lakes Steel Corporation: *G. R. Hornke*, Superintendent, Ore Handling and Sintering, Blast Furnace Div., Great Lakes Steel Corp., Detroit, Mich., and *R. E. Powers*, Sales Engineer, Koppers Co., Inc., Pittsburgh, Pa.

Control and Proportioning of Sinter Plant Raw Materials: *J. W. Meredith*, Managing Director, and *A. M. Frankau*, Assistant Manager, Huntington, Heberlein and Co., Ltd., London, England

Meramec Ore Deposits in Missouri: *F. G. Snyder*, Assistant to Chief Geologist, St. Joseph Lead Co., Bonne Terre, Mo.

Model Blast Furnace Investigations: *Norwood Melcher*, Chief, Pyrometallurgical Laboratory, U. S. Bureau of Mines, Pittsburgh, Pa.

Model Blast Furnace Investigations: *M. Ed. Bonnaure*, Chef de Service au Bas Fourneau International de Liege, Ougree, Belgium

2:00 to 5:00 pm—Ivory Room

Blast Furnace Theory Session

Chairmen: *T. L. Joseph*, Professor of Metallurgical Engineering, University of Minnesota, Minneapolis, Minn., and *W. O. Philbrook*, Professor of Metallurgical Engineering, Carnegie Institute of Technology, Pittsburgh, Pa.

Laboratory Evaluation of Performance Characteristics of Various Types of Sinter: Preprinted paper by *A. M. Schwarz*, Research Metallurgist, and *M. O. Holowaty*, Chief Research Engineer, Raw Materials, Research and Development Dept., Inland Steel Co., East Chicago, Ind.

Blast Furnace Sinter-Related to Burdening and Charging: *F. R. Kik*, Senior Blast Furnace Engineer, Inland Steel Co., East Chicago, Ind.

Experimental Smelting of a Siliceous Iron Ore: Preprinted paper by *H. U. Ross*, Professor of Metallurgical Engineering, University of Toronto, Toronto, Ont., Canada

Ore and Coke in Blast Furnace Models: *T. Turnbull* and *J. B. Wagstaff*, Fundamental Research Laboratory, United States Steel Corp., Monroeville, Pa.

2:00 to 5:00 pm—Crystal Room

Coke Session

Chairman: *J. F. Holt*, Superintendent, Coke and Coal Chemicals Dept., United States Steel Corp., Fairless Hills, Pa.

Canadian Coals in Ferrous Metallurgy: Preprinted paper by *A. Ignatieff*, Chief, Division of Fuels, *J. C. Botham*, Scientific Officer, Fuels Div., and *J. H. Walsh*, Scientific Officer, Department of Mines and Technical Surveys, Mines Branch, Ottawa, Ont., Canada

Methods of Banking Coke Ovens: *A. D. Shattuck*, Coke Plant Superintendent, Great Lakes Steel Corp., Detroit, Mich.

Production and Use of Ferro Coke: *Graham Granger*, Vice President, Engineering and Research, *M. J. Lach*, Chemical Engineer, and *John Mitchell*, Director of Research, Eastern Gas and Fuel Associates, Boston, Mass.

Tuesday, April 7

9:30 am to 12:15 pm—Ivory Room

Manufactured Blast Furnace Burdens Session

Chairmen: *D. C. Brown*, Assistant Director of Research, Graham Research Laboratory, Jones & Laughlin Steel Corp., Pittsburgh, Pa., and *M. O. Holowaty*, Chief Research Engineer, Raw Materials, Research and Development Dept., Inland Steel Co., East Chicago, Ind.

Pellets: *J. B. Hill*, Technical Assistant, Blast Furnaces, Bethlehem Steel Co., Bethlehem, Pa.

Making of Self-Fluxing Sinter and the Blast Furnace Practice With Its 100% Sinter Burden: Preprinted paper by *Y. Doi*, Doctor of Technology, Assistant Manager, and *K. Kasai*, Superintendent, Blast Furnaces, Sumitomo Metal Industries Ltd., Kokura Steel Works, Kokura, Japan

Flux Sintering Procedures: *K. Kodama*, Superintendent, Iron Making Dept., Yawata Iron and Steel Works, Yawata, Japan

Scottish Experience With Fluxed Sinter: Preprinted paper by *E. H. Baldwin*, Blast Furnace Manager, Clyde Iron Works, and *I. M. Mathieson*, Blast Furnace Manager, Ravenscraig Steel Works, Colvilles, Ltd., Glasgow, Scotland

Flux Sintering Procedures: *J. B. Hill*, Technical Assistant, Blast Furnaces, Bethlehem Steel Co., Bethlehem, Pa.

Mixing and Conditioning of Sinter Plant Feed: *Hans Rausch*, and *G. Brandes*, Lurgi-Chemie, Frankfurt-am-Main, Germany

Sinter Feed Mixing Circuits, *T. L. Myron*, Technologist, and *R. T. Johnson*, Assistant Technologist, Applied Research Laboratory, United States Steel Corp., Monroeville, Pa.

9:30 am to 12:15 pm—Room #1

Coal Chemicals Session

Chairmen: *N. Isenberg*, Chief Chemist, Coke Plant, Inland Steel Co., East Chicago, Ind., and *W. H. Weise*, Works Metallurgist, American Steel and Wire Div., United States Steel Corp., Cleveland, Ohio

Application of Tar Pressure Decantation for Dehydration and Chloride Reduction: Preprinted paper by *P. J. Farley*, Foreman-Coal Chemicals, and *J. C. Winkley*, Chemical Engineer, Fairless Works, United States Steel Corp., Fairless Hills, Pa.

Problem of Coke Oven Ammonia Recovery: *James Black*, Senior Technologist, United States Steel Corp., Monroeville, Pa.

Chemicals in Coal Tar: *C. K. M. Winne*, Technical Director, Chemicals, Tar Products Div., Koppers Co., Inc., Pittsburgh, Pa.

World Market for Coal Chemicals: *J. A. DeCarlo*, Chief, Coke and Coal Chemical Section, and *H. Perry*, Chief, Branch Bituminous Coal Research, United States Bureau of Mines, Washington, D. C.

2:00 to 5:00 pm—Ivory Room

Joint Session

Chairmen: *H. U. Ross*, Professor of Metallurgical Engineering, University of Toronto, Toronto, Ont., Canada, and *J. H. Walsh*, Scientific Officer, Department of Mines and Technical Surveys, Mines Branch, Ottawa, Ont., Canada.

Quo Vadis: Blast Furnace?: *M. O. Holowaty*, Chief Research Engineer, Raw Materials, Research and Development Dept., Inland Steel Co., East Chicago, Ind., and *J. B. Austin*, Administrative Vice President, Research and Technology, United States Steel Corp., Pittsburgh, Pa.

A New Electric Direct Reduction Process Producing Steel or Pig Iron: Preprinted paper by *Albert De Sy*, Head of Metallurgical Dept., University of Ghent, Ghent, Belgium

Annual Fellowship Dinner

Tuesday, April 7

6:30 pm—Ivory Room

Reception and Cocktail Party for dinner guests

7:00 pm—Gold Room

Annual Fellowship Dinner

Toastmaster: *Joseph Holland*, Special Assistant to Publisher, "St. Louis Post-Dispatch," St. Louis.

Speaker: *William McDonnell*, President, U. S. Chamber of Commerce, and Chairman of Board of First National Bank in St. Louis, St. Louis.

F. M. HAMILTON
PAST-CHAIRMAN
Jones & Laughlin Steel Corp.

J. W. DUNCAN
CHAIRMAN
U.S. Steel Corp.

R. E. POWERS
VICE-CHAIRMAN
Koppers Co., Inc.

Blast Furnace, Coke Oven, and Raw Materials Committee

Executive Board

J. W. Duncan
U.S. Steel Corp.
R. E. Powers
Koppers Co., Inc.
F. M. Hamilton
Jones & Laughlin Steel Corp.
W. F. Huntley
Jones & Laughlin Steel Corp.
R. W. Shearman, *Treasurer*, AIME

Program Committee

J. Chisholm, *Chairman*
U.S. Steel Corp.
D. C. Brown
Jones & Laughlin Steel Corp.
J. F. Holt
U.S. Steel Corp.
F. G. Anderko
Bethlehem Steel Co.
M. O. Holowaty
Inland Steel Co.
P. L. Richards
U.S. Steel Corp.
H. U. Ross
University of Toronto

Finance Committee

W. O. Bishop, *Chairman*
Inland Steel Co.
N. W. Lindsay
F. P. MacNaughton
R. H. White

Membership Committee

V. J. Nolan, *Chairman*
National Carbon Co.
W. E. Conway
J. Schreiner
R. C. Mohr

W. F. HUNTLEY
SECRETARY
Jones & Laughlin Steel Corp.

V. W. JONES
CHAIRMAN
Armco Steel Co.

M. F. YAROTSKY
PAST-CHAIRMAN
U.S. Steel Corp.

National Open Hearth Steel Committee

D. R. LOUGHREY
VICE-CHAIRMAN
Jones & Laughlin Steel Corp.

Executive Board

R. P. Carpenter
Republic Steel Corp.
C. E. Carr
Weirton Steel Co.
C. W. Conn
Ford Motor Co.
B. Dagan
Kaiser Steel Corp.
H. B. Emerick
Jones & Laughlin Steel Corp.
R. R. Fayles
Lukens Steel Co.
G. R. Fitterer
University of Pittsburgh
T. G. Harkins
Crucible Steel Co. of America
T. D. Hess
Youngstown Sheet & Tube Co.
C. M. Kay
U.S. Steel Corp.
A. K. Moore
Steel Co. of Canada, Ltd.
L. W. Moore
Wheeling Steel Corp.
R. Smith
Colorado Fuel and Iron Corp.
J. M. Stewart
Hickman, Williams and Co.
M. Tenenbaum
Inland Steel Co.
T. V. Wainwright
Bethlehem Steel Co.

Technical Program Committee

D. R. Loughrey, *Chairman*
T. D. Hess
H. B. Emerick

Finance Committee

L. W. Moore, *Chairman*
J. P. Bankson
A. E. Bickell
H. P. Day
J. F. Donnell
J. MacBeth, Jr.
W. J. McGregor

R. W. SHEARMAN
SECRETARY AND TREASURER
AIME

National Open Hearth Steel Committee Reports

Local Section Activities

C. E. MOYER

Republic Steel Corp.
Buffalo, N. Y.
Chairman
Buffalo Section

Buffalo Section

In 1958, the Buffalo section presented its first two technical papers as entries for the *McKune Award*. Prepared by G. F. Newton, Steel Co. of Canada, and D. M. McFarlane, Dominion Foundries & Steel Ltd., the papers were previewed at the technical session. The Open Hearth Suppliers' committee provided their usual well-prepared and patronized luncheon and cocktail party. The annual banquet was well attended and paid very close attention to a thought-provoking talk provided by F. S. Eckhardt, asst. general manager, Bethlehem Steel Corp., Lackawanna, N. Y., on his *Personal Experiences in the USSR* during a recent, extensive trip.

At the ninth Annual Meeting, the outgoing officers, Chairman John R. Atkinson, Vice Chairman Charles E. Moyer, and Secretary Harry A. Morlock, were complimented by the assemblage for having efficiently conducted the affairs of the Section during their two years of office. Mr. Moyer, open hearth supt., Republic Steel Corp., Buffalo, accepted the gavel as Chairman for 1959-60. His Vice Chairman is Robert M. Jordan, asst. general manager, Bethlehem Steel Corp., Lackawanna. Mr. Morlock will remain as the Section Secretary.

The ninth annual Fall Meeting was held on November 11th in the Statler-Hilton Hotel. The day started for the 211 registrants with a visit to the Ford Stamping plant in Woodlawn, followed by a well-conducted technical session in the afternoon.

The fifth annual golf party of the Section was held at Wanakah Country Club on May 22nd, 150 members registering. The Suppliers' committee provided an excellent luncheon, and following the tournament (in which most of the registrants participated) the Committee supplied furnishings for a cocktail party. Prizes for golf scores and other lesser achievements were dispensed at the annual dinner. Buffalo section regards the annual golf party as an excellent mid-season get-together to maintain the high standard of good fellowship, for which the Section is noted.

M. E. NICKEL

International Harvester Co.
Chicago, Ill.
Chairman
Chicago Section

Chicago Section

The spring dinner-meeting was held at Phil Smidt's Restaurant, Hammond, Ind., on May 5th. J. E. Harrod, U. S. Steel Corp., served as technical chairman of the program, which was highlighted by the presentation of a paper on *Bottom Practices at No. 1 Open Hearth, Lackawanna Plant*, by R. M. Jordan, Bethlehem Steel Corp.

The 11th annual golf party was held at the Midlothian Country Club on September 9th. Total attendance at this affair was 491, with 227 participating in the golf tournament.

The fall dinner-meeting was held at Phil Smidt's on October 6th, with J. E. Tucker, U. S. Steel Corp. Gary Steel works, serving as technical chairman. The entire program was devoted to an illustrated talk by M. F. Yarotsky, U. S. Steel Corp., ret., who gave an enlightening description of his trip to Russia, including visits to Russian steel plants. At the close of the meeting, Mr. Yarotsky was presented with a plaque and lifetime chapter pass as a testimonial of his many years of service and participation in the activities of the chapter.

The all day Off-the-Record Meeting was held at the Del Prado Hotel on March 11, 1959. Subjects discussed included open-hearth charge oxides, direct reduced iron as a charge material, use of clinker dolomite, and repairs to open-hearth roofs with fire on. In the afternoon quality session, the topics covered were control of heat analyses, cleanliness of 1030 steel, hot-topping practices, and a survey of molds and stools.

Officers of the Section for the coming year are: M. E. Nickel, Wisconsin Steel works, International Harvester, Chairman; A. M. Kroner, Inland Steel Co., Vice Chairman; W. R. McLain, U. S. Steel Corp., South works, Secretary-Treasurer.

Cleveland Section

Membership of the Section has increased during the past year from 112 to 154. This includes new members from the Empire Reeves Steel Corp., Mansfield. Ohio. Attendance at meetings has also increased considerably. The majority of meetings are of the panel-discussion type, utilizing as speakers melters, general foremen, metallurgists, and combustion dept. personnel. Discussion following the talk has been lively, indicative of interest in the programs.

Officers elected for a two year term are: E. J. Sobey, asst. supt. Jones & Laughlin Steel Corp., Chairman; E. G. Kondas, asst. supt., Republic Steel Corp., Vice Chairman; L. Svete, asst. supt. National Tube Co., Secretary; W. M. Nielsen, general foreman, National Tube Co., Treasurer.

A dinner-dance was held on June 19th at the Lake Shore Hotel. The affair was attended by 91 couples.

E. J. SOBEY

Jones & Laughlin Steel Corp. Cleveland, Ohio Chairman Cleveland Section

Detroit Section

The activities of the Section during the past year included two technical meetings and a golf outing, the first meeting being held at the Rackham Engineering Society Building on February 6, 1958. Ninety persons attended the dinner and 110 attended the meeting. The latter consisted of a symposium on steel mill spraying equipment and techniques. The panel was composed of representatives from the four local steel plants.

The second meeting was held in the auditorium of the Ford Motor Co. central office building. R. W. Joseph, Inland Steel Co., presented his *McKune Award* paper to the 85 people in attendance. His topic was *Mold Conditions*. Edward C. Rudolphy, U. S. Steel Corp., presented his *runner-up* paper on *Nozzle Characteristics*.

M. F. Yarotsky, U. S. Steel Corp., ret., opened the 1959 season with his *Impressions of the Russian Steel Industry*. This meeting was held on February 18th at the Rackham Engineering Society, and was attended by 120 persons.

Current officers of the Section are: H. W. Clark, Ford Motor Co., Chairman; H. Moyer, McLouth Steel Corp., Vice Chairman; B. Ramage, Great Lakes Steel Corp., Secretary; J. C. Brown, J. & L. Stainless div., Treasurer.

Coming events for 1959 will include a half-day meeting in May followed by a visit to a local steel plant with a banquet in the evening. The second annual golf party will be held in September. The year will conclude with a dinner-meeting at the Engineering Society in November.

H. W. CLARK

Ford Motor Co. Detroit, Mich. Chairman Detroit Section

Eastern Section

The 12th annual technical conference convened on October 10th at the Warwick Hotel in Philadelphia. The meeting was attended by 251 members. The first order of business, following the opening remarks by the Chairman, was the announcement of awards for the prize-winning papers. First prize was presented to Fred A. Leslie, Jr., Bethlehem Steel Co., Sparrows Point, Md., for his paper, *Air Infiltration Into Fuel-fired Equipment*. William Sabolchy received second prize for his paper, *Mold Scrapping Program at John A. Roebling's Sons Corp.* The balance of the morning session took the form of a panel discussion.

The afternoon session was devoted to three speakers: M. F. Yarotsky, U. S. Steel Corp., ret., *Latest Report on Russian Steelmaking;* W. S. Debenham, U. S. Steel Corp., *Quality and Development of Modern Open Hearth Refractories;* and F. E. Bird, Jr., Lukens Steel Co., *New Approaches to Head and Eye Injury Prevention in Open Hearth Operations.*

Following a reception in the ballroom, the Fellowship Dinner featured Leo F. Reinartz, who delivered an abbreviation of his paper, Steelmaking—USA (the first installment of which appears in this issue).

The Suppliers' committee and the Eastern section experienced a sorrowful loss in June when R. L. Batteiger, Suppliers' chairman passed away.

The Coatesville Country Club, Coatesville, Pa., was the scene of the Section's second annual golf party on June 20th. The somewhat inclement

G. S. BALDWIN

Baldwin-Lima-Hamilton Corp.
Burnham, Pa.
Chairman
Eastern Section

weather was braved by 128 members and guests. Prizes donated by the Suppliers' committee were awarded to the outstanding golfers. A buffet lunch was served.

Plans for 1959 include a plant visit to E. J. Lavino & Co. and G. & W. H. Corson Inc., followed by a golf party at the Plymouth Country Club, Plymouth Meeting, Pa., on June 15th, and the annual technical conference scheduled for October 9th at the Warwick Hotel.

Northern Ohio Section

The Section will meet on March 12, 1959 for an Off-the-Record Meeting. William T. McKeon, Union Carbide Metals Service, will speak on *Alloys for the Present and Future*. Other speakers will be Robert Edwards, supt. LD furnaces, Jones & Laughlin Steel Corp., *LD Process;* R. G. Watson, Republic Steel Corp., *Ingotrol—Weighing Ingots as Teemed;* R. C. Oswald, supt. open hearth, Sharon Steel Corp., *Refractory Gunning for Open Hearth Furnace Maintenance;* John Beale, asst. chief metallurgist, Republic Steel Corp., *High Carbon Rimming Steels;* T. A. Thompson, asst. open hearth supt., Weirton Steel Co., *Increased Open Hearth Production with the Use of Oxygen.*

The annual golf party will be held on June 10th at the Squaw Creek Country Club, Youngstown, Ohio.

E. BRANDON

U. S. Steel Corp.
Youngstown, Ohio
Chairman
Northern Ohio Section

Pittsburgh Section

The 13th annual Off-the-Record Meeting was held on November 7th at the Penn-Sheraton Hotel. The meeting encompassed the efforts of all the local divisions of AIME: the Coal div., Institute of Metals, Petroleum, Minerals and Metals Economic Committee, and the NOHC. Mr. F. M. Richmond and J. N. Albaugh, NOHC, served as General Chairmen, capably assisted by their various Division Chairmen and committees.

There were 878 registrants for the various technical sessions. A highlight of the open-hearth session was the participation of Dr. J. H. Chesters, asst. director of research, The United Steel Companies Ltd., who discussed one of his favorite subjects, *The Factors Controlling Iron Oxide Deposition in Open Hearth Furnaces.* J. M. Vonfeld presided as toastmaster at the fellowship dinner. There were 405 members and guests of AIME/NOHC. The Section was fortunate to have in attendance Augustus B. Kinzel, 1958 AIME President; A. W. Thornton, AIME Vice President; V. W. Jones, NOHC Chairman; D. R. Loughrey, NOHC Vice Chairman; L. F. Reinartz, AIME and NOHC Past-President; R. W. Shearman, NOHC Secretary; D. C. Johnston, The Metallurgical Society Asst. Secretary; and Ernest Kirkendall, AIME Secretary.

R. M. BARNHART

Alco Products Inc.
Latrobe, Pa.
Chairman
Pittsburgh Section

Special recognition was paid to W. L. Kerlie and J. H. Richards (Toy Award winners), and to J. W. Kersting *(Leo F. Reinartz AIME-NOHC Award* winner). M. W. Lightner, vice president, U. S. Steel Corp., introduced Glenn B. Warren, vice president, General Electric Co., principal dinner speaker.

Newly elected officers for the Pittsburgh section are R. M. Barnhart, Alco Products Inc., Chairman; E. E. McGinley, U. S. Steel Corp., Vice Chairman; J. G. Bassett, Acid Open Hearth Research Ass'n., Secretary; J. H. Smith, Steel Publications, Treasurer.

The golf party was held at the Edgewood Country Club on June 16th, 212 persons participating. The dinner was attended by 400 people. H. R. Loxterman, with the balance of his committee on arrangements, awarded the many prizes contributed by the Suppliers'. R. M. Barnhart presided as toastmaster.

Southern Ohio Section

The 22nd annual technical conference was held on October 3rd and 4th in the Deshler-Hilton Hotel, Columbus, Ohio. O. V. Ireland, supervising metallurgist, Armco Steel Corp., and T. J. Murray, asst. to supt., open hearth, Armco Steel Corp., served as Co-chairmen for the morning operating session. M. F. Yarotsky, U. S. Steel Corp., ret., spoke on *Impressions of the Russian Steel Industry*. Papers on operating problems were presented by F. Williams, Armco Steel Corp.; R. K. Thornberry, Acme-Newport Steel Co.; and G. Reisenberg, Armco Steel Corp.

Mr. Thornberry, supt. of steel melting at Acme, and T. Burney, general foreman, No. 1 shop, Armco Steel Corp., served as Co-chairmen of the afternoon session on furnace practice. Papers were presented by J. Curtis, M. Sample and O. Eyre, Armco Steel Corp.; and E. J. Whittenberger, U. S. Steel Corp. There were 172 registered for the sessions.

The Fellowship Dinner was held at the Deshler-Hilton Hotel. V. W. Jones, National Chairman, NOHC, was toastmaster. The speaker was Dr. Tennyson Guyer, Finlay, Ohio.

Officers for the Section are W. W. Bergmann, supt., No. 1 open hearth shop, Armco Steel Corp., Middletown, Chairman; and G. E. Brehm, steel plant statistician, Armco, Secretary-Treasurer.

W. W. BERGMANN

Armco Steel Corp.
Middletown, Ohio
Chairman
Southern Ohio Section

Southwestern Section

The Spring Meeting was held at the Lennox Hotel in St. Louis, Mo., on Feb. 7, 1958. Approximately 150 persons registered.

The Globe Trotters of the Section held their annual Fall Meeting in Birmingham on October 9th and 10th. Host for the meeting was the Tennessee Coal & Iron div., U. S. Steel Corp., Fairfield, Ala. The Globe Trotters are pleased to have The TC&I div. a member of the Section.

Members and guests of AIME visited TC&I on October 9th. They returned to the Dinkler-Tutwiler Hotel for the Suppliers' cocktail party and the Fellowship Dinner. W. E. Crouch, Jr., vice president in charge of operations, was the speaker.

The technical session was held at the Dinkler-Tutwiler Hotel on October 10th; 185 attended.

G. GROSVENOR

Colorado Fuel and
Iron Corp.
Pueblo, Colo.
Chairman
Southwestern Section

Western Section

The current season began with a meeting held Dec. 17, 1958. Speaker for the meeting was Dr. R. W. Truesdail, founder and director of the Truesdail Laboratories. The subject of his talk was *Peeps at Things to Come*. Speaker at the Jan. 22, 1959 meeting was G. W. Teskey, open hearth supt., Bethlehem Pacific Coast Steel Corp., who spoke on *Carbide Black in Fuel Oil*.

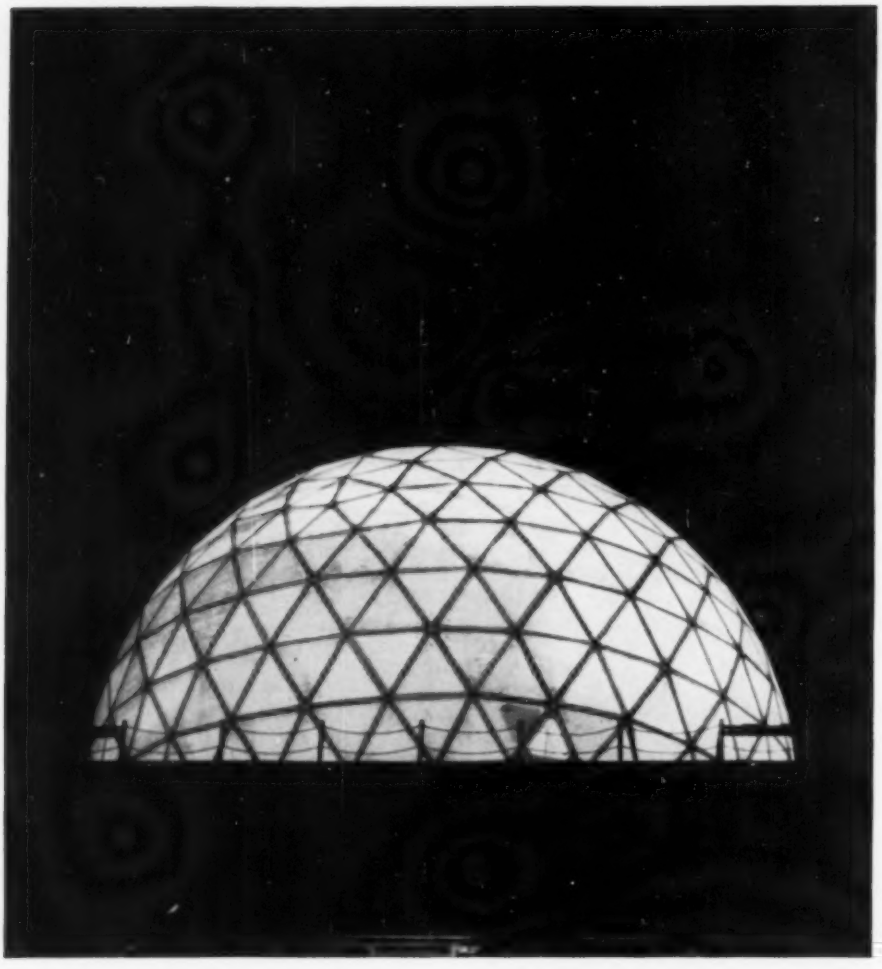
A new basic oxygen steelmaking process will be seen at the Kaiser Steel Corporation's Fontana plant during the April meeting. The following month, J. J. Golden, chairman, operating committee, steel production, U. S. Steel Corp., will speak on open-hearth roofs. Another trip has been planned tentatively for June; location will be the U. S. Lime Products div. of The Flintkote Co., in Apex, Nev.

Officers of the Western section are J. L. Venturini, fuel engineer, Bethlehem Pacific Coast Steel Corp., Los Angeles, Chairman; Robert Prout, open hearth supt., Columbia-Geneva Steel div., U. S. Steel Corp., Torrence, Vice Chairman; and S. G. Bishell, southern district sales manager, U. S. Lime Products div., The Flintkote Co., Los Angeles.

J. L. VENTURINI

Bethlehem Pacific
Coast Steel Co.
Los Angeles, Calif.
Chairman
Western Section

THE ARCTIC EYE THAT NEVER SLEEPS



This plastic radome houses a radar antenna constantly scanning the skies to detect the presence of aircraft. A line of these radars provides early warning of any threatening approach to the North American continent.

The Distant Early Warning Line is now on perpetual guard duty. Spanning the Arctic from Baffin Island to Alaska, this great system was conceived at the Lincoln Laboratory of M.I.T. and produced under the leadership of Western Electric.

But first the DEW Line had to be engineered into a workable system. This was done at Bell Telephone Laboratories.

The obstacles were formidable. Conventional means of communication—telephone poles, cables and even line-of-sight microwave radio—weren't feasible. A complicated system had to be made to operate reliably in a climate so cold that outdoor maintenance is impracticable farther than a few hundred feet from heated habitation.

Whenever possible, Bell Laboratories engineers utilized well-proven art. But as it became necessary, they innovated. For example, they designed and directed the development of a new and superior radar which automatically scans the skies, pinpoints a plane and alerts the operator.

To reach around the horizon from one radar station to another, they applied on a massive scale a development which they pioneered—transmission by tropospheric scatter. Result: at a DEW Line Station you can dial directly a station more than a thousand miles away and converse as clearly as with your home telephone.

Bell Laboratories' contribution to the DEW Line demonstrates again how telephone science works for the defense of America.

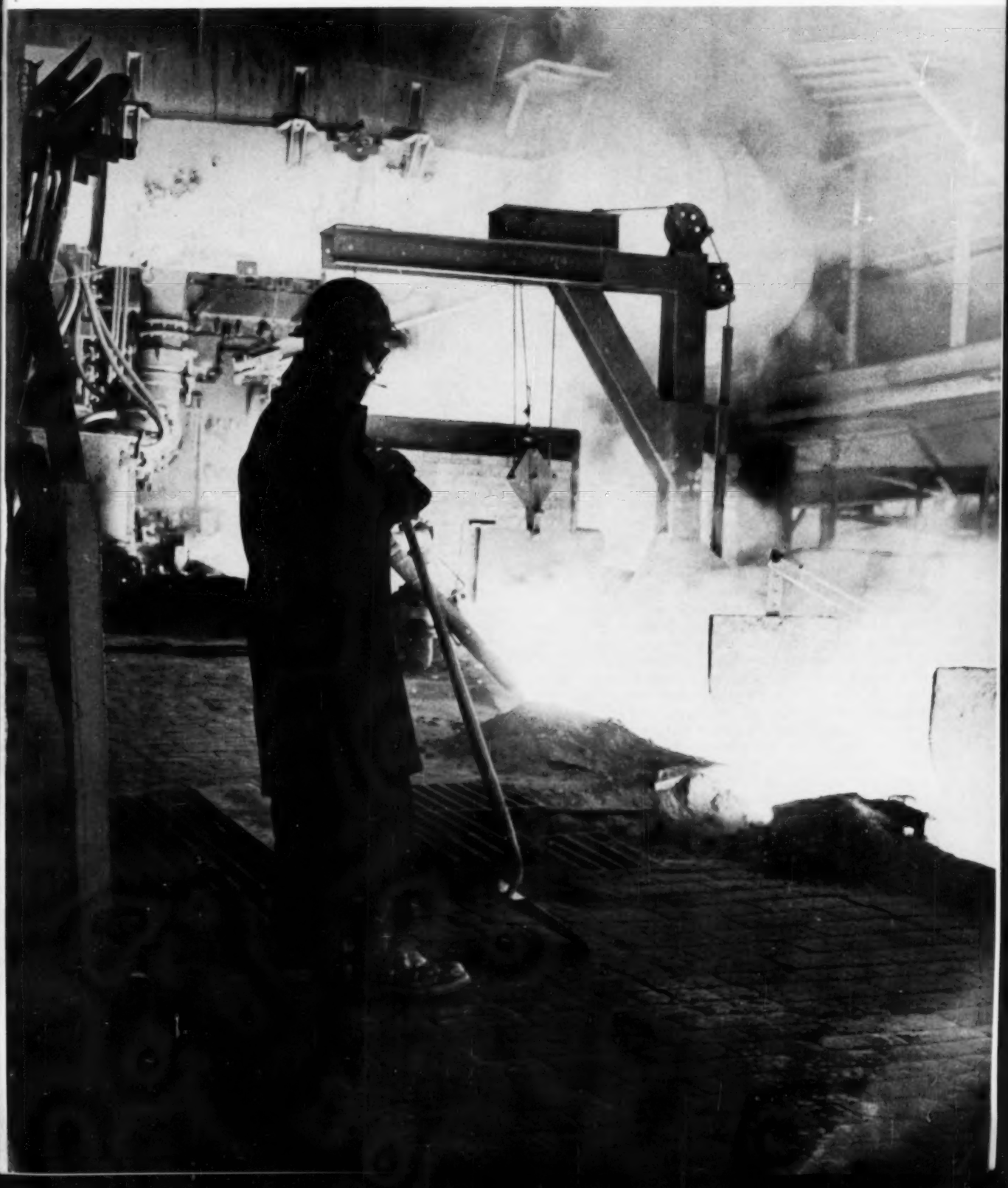
BELL TELEPHONE LABORATORIES

WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

Gold is for the mistress—silver for the maid—
Copper for the craftsman cunning at his trade.
Good said the Baron, sitting in his hall,
But Iron—Cold Iron—is master of them all.

—Rudyard Kipling

Bethlehem Steel, Lackawanna Plant
Photo by David Cain



LD OPERATIONS AT ALIQUIPPA

Basic oxygen steelmaking has been going on at J & L's Aliquippa works since November 1957. From this year's AIME Annual Meeting, JOURNAL OF METALS *presents a report which shows the remarkable production records being chalked up by this relatively new process.*

by D. R. Loughrey

SEVERAL years ago it was decided to install a strip mill at the Aliquippa works of Jones & Laughlin Steel Corp., in addition to continuous weld and electric weld pipe mills. This program made it necessary to produce a minimum of 20,000 tons more steel per month at Aliquippa with the existing iron supply, while the new product mix made it desirable to produce a higher percentage of low-nitrogen steel. In order to accomplish these twin objectives, the various oxygen processes being used in Europe were investigated. It was decided that the LD process offered the most economical means of producing the desired results, and these expectations are being borne out in actual operation. The process is capable of melting much higher percentages of scrap than the conventional bessemer converters, while the diversion of iron from the duplex operation releases more open-hearth furnaces for melting scrap. In this way, the desired increase in plant capacity has been achieved.

This plant began operation on November 11, 1957, and it is presently producing 81 net tons per heat, using one furnace, while the other furnace is either being relined or standing by. Allowances were made for the future installation of a third furnace.

The three major operating areas within the building are designated as the charging aisle, furnace aisle, and teeming aisle. Fig. 1 shows the plan view of the plant, while Fig. 2 shows the building in cross section, with the location of the major equipment items and the building elevations.

Charging aisle

Hot metal comes directly from the blast furnace to the charging aisle in 190-ton, self-dumping, submarine-type ladle cars. The transfer ladles rest on scales while being filled. Flux materials are brought to the plant in bottom-dump hopper cars or trucks and enter the conveyor system through the track hopper shown in Fig. 1. An underground conveyor empties the track hopper and discharges into the skip hoist bucket. A single-bucket skip hoist elevates the material to the surge hopper, and a self-propelled belt tripper distributes the material into the proper overhead bin. The conveyor system and storage bins are designed to enable the material transfer to be accomplished on a one-shift basis. A self-propelled weigh larry car, servicing both furnaces, is used to weigh out the initial flux charge, and this car discharges through a chute directly into the furnace. Any additional flux added during the blowing period is weighed by separate stationary weigh hoppers which allow the larry car to be recharged with no loss of time between blows.

On the charging floor are the control pulpits, offices, instrument repair shop, and the scrap charging car and tracks. The scrap charging car has four individually tilting scrap boxes; it is moved from the scrap-receiving position to the furnaces by an electric mule. Prepared scrap is transferred by magnet from gondola cars to the scrap charging car which is positioned on the scrap scales, and the weight of each box is recorded. The charging car is then positioned in front of the furnace and the appropriate number of boxes of scrap are charged into the furnace by moving the car so that the box to be charged is directly in front of the furnace mouth. The furnace is rotated forward in order to distribute it over the furnace bottom, and it is then returned back to the charging position where the charging crane has the hot metal ladle in position to pour into the furnace.

Furnace aisle

At ground level, beneath the furnaces, are the transfer tracks for the steel ladles and the slag pots. Steel ladles are moved from the furnace aisle to the teeming aisle by a self-propelled transfer car, powered by an electric motor through a cable reel arrangement. During the tapping of the furnace or the transfer from the furnace aisle to the teeming aisle, the car can be controlled either from the control pulpit or a station at the teeming aisle side of the charging floor.

The furnaces are designated as the eccentric type due to the fact that the plane of the mouth is not

D. R. LOUGHREY is coordinator of steelmaking operations, Jones & Laughlin Steel Corp., Pittsburgh, Pa.

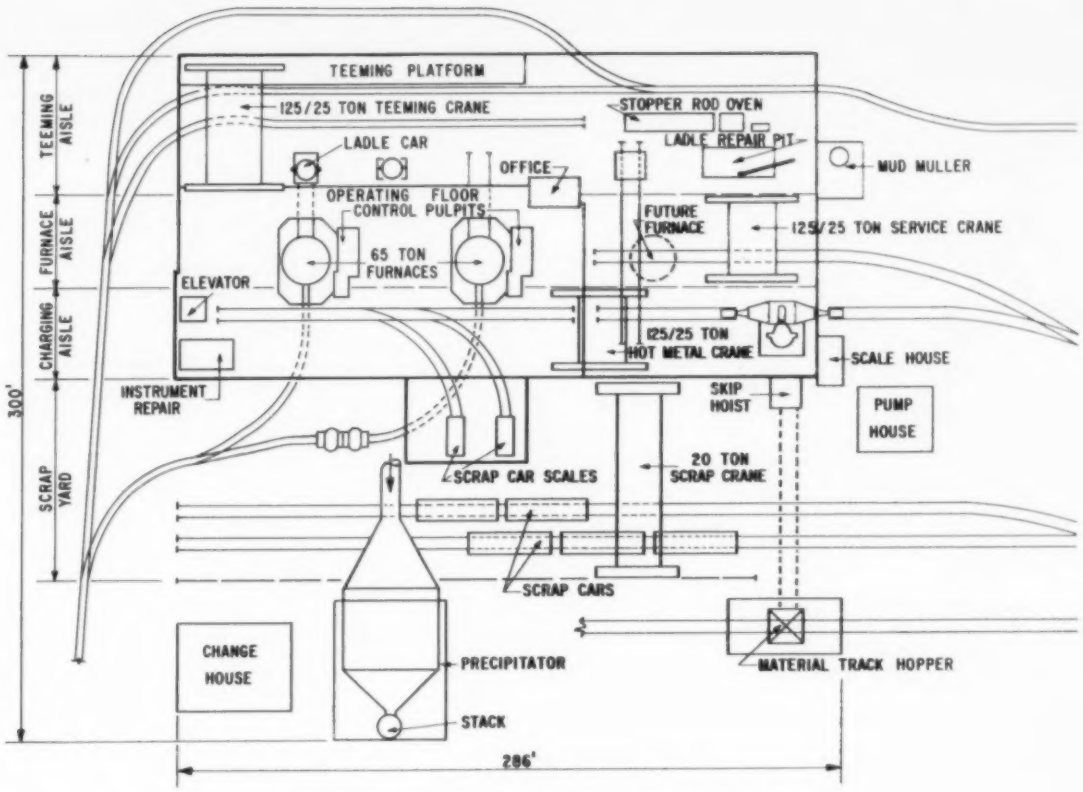


Fig. 1—Plan view at operating-floor level of Aliquippa plant.

perpendicular to the vertical axis of the furnaces. The trunnions are fitted with anti-friction bearings, and two 130-hp mill-type drive motors connected to a single gear reducer unit drive the furnace through a flexible coupling. The furnaces can be turned through 360° and are controlled by means of variable voltage systems. Each furnace has an identical system; it is possible to operate either furnace from either control system. A taphole is located on the short side of the nose cone, 5½ ft back from the lip; during pouring, the furnace is turned toward the teeming aisle to a degree which keeps the top of the slag layer at the furnace lip. In this way the slag is effectively prevented from entering the ladle with the steel.

The fume hoods over the furnaces are made up of water-cooled panels. These panels are connected to provide parallel water channels with the water moving upwardly. A welded pipe structure not only supports the individual cooling panels, but also serves as the cooling water supply and return lines. Each vertical water channel is made up of three separate panels, and there is a separate inlet and outlet connection for each channel.

The hood is supported by a wall crane which enables it to be moved away from the mouth of the furnace during the relining. With the hood in the operating position it abuts the spark box in which the large particles of dust and slag are removed and the exhaust gases are cooled and conditioned. The upper portion of the spark box is water-cooled and contains the gas-cooling water spray nozzles. The lower portion is refractory lined and has provision for retaining the large particulate matter, while the fine dust particles that are removed by this initial treatment are carried off by the excess water. The gas exit from the spark box is near the top and, therefore, the gas flow goes through a 180° direction reversal which removes the excess entrained water. The ducts from each spark box enter a header on the outside of the building and thence to the precipitator. The design of the hood system was complicated by the desire to keep the service crane as low as possible.

The oxygen lances, 43 ft 8 in. long by 5½ in. OD, copper tipped, are water-cooled and have a dual hoist arrangement which permits immediate replacement of a lance that becomes defective. Additional lances are stored adjacent to the lance hoists so that the replacement of defective lances is a simple operation of disconnecting the water and oxygen hoses and then connecting the new lance. The lance hoists have motorized trolleys and are located so that in the *up* position, the bottom of the lance clears the service crane trolley. In normal operation, the lance is raised to a point to clear the hood. The lance, when lowered, enters the hood through a funnel-shaped opening and, when at the proper elevation, lance clamps are actuated to hold the lance firmly in position during the blowing period.

Normal operation of the lances is controlled from the control pulpit where there are lance position indicators. The lance hoists have multiple step controls so that high speeds can be used for the initial movement and low speeds used for exact positioning. Appropriate interlocks have been included to protect against improper operation of the lance in relation to the furnace position, oxygen or water flow, lance clamp actuation, etc.

There is a control pulpit adjacent to each furnace from which most of the operating functions can be controlled. The pulpit operator in many cases receives his instructions by hand signals from someone on the operating floor. In addition, a public address system is used to communicate with those people not within sight of the control pulpit. There are also separate operating stations for the ladle transfer cars and lance hoists and, through means of interlocks, the control of this equipment can be transferred from the pulpit to the station adjacent to the equipment. Appropriate recording and indicating instruments have been installed to assist in the operation of the plant.

Teeming aisle

All the normal pouring and ladle repair operations common in an open-hearth shop are done in this aisle. A diesel locomotive is used to pull the mold cars away from the pouring platform. This aisle may be extended when necessary to provide for an additional pouring platform. A spur track at the teeming platform provides space for pots to receive ladle slag.

Scrap yard

Very little ground area was allocated for scrap storage, as the normal procedure is to receive scrap in gondola cars for transfer directly to the scrap charging car. This eliminates an intermediate scrap-handling operation. Sufficient trackage has been provided to spot 12 cars of scrap, which is approximately 1 day's requirement. The charging floor extends into the scrap yard, which permits the scrap charging car to be positioned under the scrap crane. The car then remains on the scale until the heat in progress has been blown. After the heat temperature has been taken, the scrap charge is then trimmed to the required weight.

Table I. Operating Statistics for Jones & Laughlin, Aliquippa Works, LD Plant for February 1959 (28 Days)

Total tonnage for 28 days, net tons	62,340
Number of heats	747
Avg wt per heat, net tons	83.45
Avg time per heat, tap to tap, min	52.55
Avg tons per hr, tap to tap	95.28
Avg time per heat, charge to tap, min	37.58
Avg tons per hr, charge to tap	133.24
Avg blowing time, oxygen on, min	20.61
Total oxygen consumed, cu ft	95,437,400
Oxygen consumed per heat, cu ft	127,761
Oxygen consumed per ton, cu ft	1,531

Furnace Charge	Tons	Pct of Charge
Steel scrap	22,468	31.34
Hot metal	48,362	67.64
Scale	862	1.20
Total charge	71,692	100.00

Alloys and Fluxes	Lb	Lb per Ton
Ferro-manganese	723,000	11.71
All other alloys	53,000	0.85
Lime	8,600,000	138.00
Spar	580,000	9.30

Yield	Tons	Fe, Pct	Gross, Pct
Ingots	62,340	90.81	86.49
Skulls	1,295	1.43	1.80
Butts	1,283	1.87	1.78
Dust	754	0.72	1.05
Total yield	65,672	94.83	91.12
Unaccountable loss	6,408	5.17	8.88

Lining Life (3 Months) (10 Linings)
Avg heats per lining—181.60 (max 271)
Avg tons per lining—14,812
Lb of brick per ton—22.00
Lance Life (3 Months)
Avg number of heats per lance—458

Dust collection system

Exhaust gas from the furnaces passes through the hood and ductwork to the precipitator. Water-cooled dampers close off the duct to the furnace which is not in use. The precipitator is made up of two parallel units of three sections each, and each section has two dust collection hoppers. As the gas enters the transition section, some of the larger particles are removed due to the change in gas velocity and, therefore, a hopper is installed in the plenum chamber. All the hoppers discharge into a conveyor system that carries the dust to a common bin for removal.

Furnace lining

When a furnace comes off for lining, the following time cycle is generally required:

	8 hr cooling
16 to	24 hr skulling out by use of a Gradal
16 to	24 hr burning off scrap and repairing shell
	56 hr relining with eight men
	96 to 112 hr total time

The permanent lining in the furnace consists of burned magnesite brick, laid 4½ in. on the sides, with two soldier courses keyed in an inverted arch on the bottom. This lining is seldom damaged in operation. Its total weight is 58 tons.

The working lining at present consists of tar-bonded dolomite brick with about 55 pct MgO content. These brick are made by outside suppliers shortly before they are needed, avoiding hydration damage. The working lining of tar-dolomite brick is as follows: 18 in. on bottom, secured from dropping out during dumping operations by a steel retaining ring welded to the shell. Next, are 12 courses on the sides, 22½ in. thick in the metal holding area, consisting of 9 in. plus 13½-in. brick, 4½ in. thick. From this point to the knuckle of the cone, the brick lining is 18 in. thick. On the side walls, from the bottom to the knuckle, 4 in. of tar-dolomite ramming mix is used between the permanent and working linings.

The cone is lined with 16x3-in. brick.

On the charging side of the furnace, a 30 course panel, 27 in. thick, is used to reduce the erosion effect from charging the scrap and hot metal.

The tap hole, formed with magnesite brick, has a 5-in. hole. This hole is repiped about once every 40 heats, requiring 15 min to accomplish.

The brick in the working lining weighs 118 tons, while the ramming mix weighs 34 tons, giving a total weight in the working lining of 152 tons.

Burning in

Burning the lining in is delayed until the furnace is to be used. For this purpose, 10 coke salamanders, each holding 250 lb of coke, are placed in a row on the batching floor above the furnaces with a gas line running underneath them. When ready to start a furnace, incandescent coke from these salamanders, totalling 2500 lb, is dumped down the chute into the

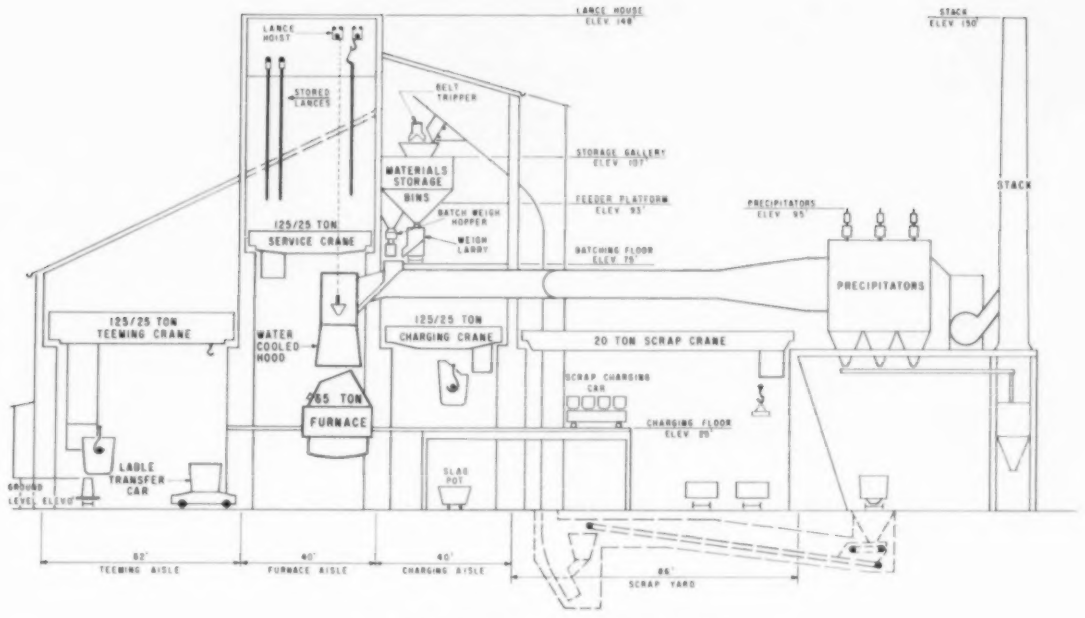


Fig. 2. Cross-section of LD plant looking south.

furnace. The lance is then lowered into the vessel and 8 to 10 lb of oxygen pressure is used. In 45 min to 1½ hr, the lining is burned in. The furnace is then ready for operation.

Oxygen generating plant

The oxygen plant consists of two units, each capable of producing 115 tons of 99½ pct O_2 per day. It is known as a mixed cycle plant, producing high pressure oxygen at 2500 psi and low pressure at 450 psi. Thus, each unit produces 112 tons of gaseous oxygen and 3 tons of liquid oxygen per day.

The storage capacity of the plant is 500,000 cu ft of gaseous oxygen and the equivalent of 6,000,000 cu ft as liquid oxygen.

A pressure of 450 lb is maintained in the oxygen line up to the furnace building. From this point, it is reduced to 225 lb. Oxygen pressure into the lances is then regulated to any desired amount by controls in the operating pulpit.

At the present time, a lance life is over 400 heats. In most cases, minor repairs will place the lance in good operating condition again.

Blowing procedure

The iron being used in the basic oxygen process at Aliquippa is low-manganese basic quality. The analysis is 0.90 to 1.70 pct Si, 0.40 to 0.50 pct Mn, 0.050 pct max S, 0.125 pct P. On account of the short haul from the blast furnaces, iron temperature under regular circumstances is good.

The operators have developed an experience chart which relates iron temperature and silicon content to the amount of coolant scrap required. In this regard, an effort is made to control the temperature from the beginning of the blow, rather than adding coolants during the blowing process. This insures against a fast temperature rise which contributes to residual silicon in the finished steel.

Scrap needed generally amounts to 26 to 32 pct of the metallic charge; it is charged into the furnace as previously described. Following the scrap, the iron is immediately poured into the furnace, which is then raised to a vertical position. The oxygen lance is lowered and the oxygen is turned on to a flow of 5000 to 6000 cfm and a pressure between 140 and 160 psi. When the lance has reached the desired distance from the surface of the metal, it is clamped in position. This distance may vary from 60 to 100 in., depending upon the blowing qualities of the iron, type of scrap being used, etc., which is a result of operating experience. Under usual or normal conditions, the lance distance is about 70 in. above the metal surface.

Shortly after the lance has been positioned, a *light* is obtained, and the blowing reactions begin. About 1 min after the light, the desired quantity of lime, spar, and scale are dumped down the retractable chute from the batching floor. These fluxes are calculated to give a finished slag with a "V" value of 2.8 to 3.0. After flux additions, blowing proceeds uninterrupted to the end. No limestone coolant is being used.

The end point of the blow on fully blown low-carbon steel is determined by the visual drop in the flame, accompanied by a definite change in the sound being emitted from the furnace. An added check is the measurement of the oxygen usage. End point control is just as accurate, and more easily attained, in the basic oxygen process than is the case with the conventional acid bessemer process. Higher carbon steels can be made by catching the carbon coming down. This is done by a visual observation and measurement of the blowing time for a given iron analysis, and can be regulated to a 10 point range below the desired finish carbon. The metal is then recarbed similarly to open-hearth practice. Experience has shown that 0.90 carbon steels can be made with a phosphorus content under 0.020 pct.

When the end point has been reached, oxygen is shut off, clamps are released, and the lance is re-

tracted through the hood. The furnace is then rotated toward the charging floor until the slag is even with the lip. The slag quantity, amounting to about 250 lb per ton of steel, makes it unnecessary to decant at this point, such as is done with the high phosphorous irons used in European practice. The temperature of the bath is then taken with a platinum immersion thermocouple. The desirable temperature range for low carbon steel is 2910° to 2940°F. This is somewhat higher than open-hearth temperatures because of the smaller mass of steel in the ladle.

If the temperature is above the tapping range, a calculated corrective amount of light scrap is added, and the vessel is rotated to distribute it in the bath. When the scrap is melted, a matter of several minutes, another temperature measurement is taken.

If the temperature is slightly on the cold side, it may be brought within range by immediately reblowing for a short period. However, if the temperature deficiency is considerable, due to a big delay, it may be necessary to add some hot metal before reblowing. When reblowing is necessary, 200 lb of carbo-coke is added to the bath before blowing; gases thus created purge the furnace of air before the oxygen exposes the surface of the metal. This prevents nitrogen absorption in the bath, which might otherwise amount to three or four points. Temperature control and correction can readily be accomplished and is, therefore, principally an effort to reduce mill delay. With proper experience, this delay can be reduced to a very small fraction of 1 pct of the total operating time.

In the case of fully blown metal, it is not necessary to take a preliminary steel test before tapping. However, when steel over 0.15 pct C is required, a carbometer test is taken as soon as a correct temperature reading has been obtained. Any error can be adjusted in a few minutes by jiggering and/or reblowing.

When the temperature and carbon are found to be correct, the furnace is rotated to a position facing the teeming aisle. The furnace is lowered until the slag approaches the lip. The taphole is opened, and the metal flows into the ladle without slag contamination. Alloys are shovelled into the ladle in the same manner as with small open-hearth heats. The ladle transfer car is then moved into the teeming aisle, where the ladle is picked up by the teeming crane. From this point on, the teeming operation is carried out in the same manner as conventionally practiced.

With an original manganese content in the iron of 0.40 to 0.50 pct, residual manganese on fully blown heats is generally found to be between 0.10 and 0.14 pct. With higher carbon heats, over 0.15 pct C, the range is generally from 0.22 to 0.30 pct residual manganese. A maximum of 0.42 pct has been obtained.

After the furnace has been emptied, it is occasionally necessary to clean some debris from the nose, or some scrap from the lance, but generally the next heat can be charged immediately.

Operating statistics

As every mill operator knows, starting up a new producing unit entails much hard work and many tribulations before a smooth working operation is achieved. It could be expected that this situation would be exceptionally adverse when the new unit involved a relatively novel and unfamiliar process. However, the operating personnel at the LD plant, with the cooperation of the contracting engineers, are rapidly improving their knowledge and operating dexterity. Each month shows a decided improvement in almost every category over the previous months, and the end does not appear yet to be in sight. Where improvement is so rapid, it is difficult to present data which is completely up to date in a report of this nature. However, the data presented is as nearly contemporary as is possible under the circumstances.

The design capacity of this plant is 63,000 net tons of ingots per month on full operation. It is now operating 20 shifts per week, with the results shown in Table I.

The force for 20 shifts-per-week operation consists of 209 men. Of these, between 50 and 75 men are split maintenance people who also perform work in the open hearth and bessemer.

Chemistry and metallurgy

The LD process has proved to be very efficient in the reduction of phosphorus and sulfur. Chemical results for January 1959, have shown: avg. P, 0.010 pct; avg. S, 0.017 pct; and avg. N, 0.003 pct. The breakdown of nitrogen results was 23 pct 0.002 or under; 54 pct 0.003; and 23 pct 0.004 or over. Of the latter ,4 pct were on reblown heats; maximum N was 0.006 pct.

Metallurgically, the steel produced by this process has proved to be of excellent quality in all the grades where it has been applied. This includes low carbon grades for hot- and cold-rolled sheets, tin plate, welded pipe, and soft wire for welding, cold forming, extrusion, etc. Higher carbon grades include light structurals and seamless tubes up to 0.40 pct C and wire up to 0.90 pct C.

The steel is very ductile and withstands bending tests easily. The low sulfurs obtained are exceptionally beneficial for welding wire.

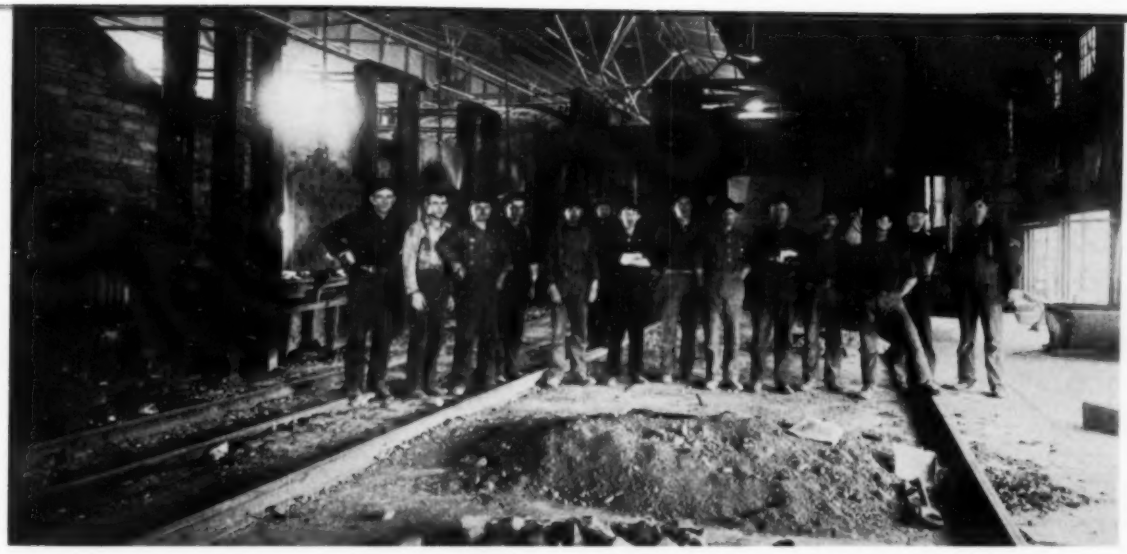
In making continuous weld pipe, slit strip is used. Because of the contact heating in this process, segregation is less serious, and the basic oxygen steel is performing well. The ductility of basic oxygen steel renders it liable to tearing, with regular dies, in the pipe-threading operation. However, this was easily overcome by changing the design of the dies.

For application on tin-plate bands, this steel has been very satisfactory. Steel defects have been less and resistance to corrosion, as established by the *pickle lag* test, has been greater than open-hearth steel. Rods for welding wire, hog wire, cold heading, and extrusion have been excellent.

To date, continuous weld pipe has accounted for 22 pct of production, tin-plate bands 62 pct, and rod mill material for wire, 10 pct. The remaining 6 pct goes into experiments on drawing quality sheets, seamless tube, hot bands for outside sale, and light structural steel, such as junior beams, angles, etc.

Conclusion

The LD or basic oxygen process chosen to be used at Aliquippa has proved to be very satisfactory and entirely adequate for handling the relatively low phosphorous iron produced from the ores which are available in America. Its speed of operation; ease of control; lining life; reduction of phosphorus and sulfur; scrap melting ability (where it is desired to use scrap rather than soft ore as a coolant); and finally the quality of its end product, are justifying the confidence placed in this process.



STEELMAKING / U.S.A.

Part I

The history of steelmaking in the United States is a fascinating story of determination, sudden tragedy, exploitation, and inventive genius rolled into one gigantic plot. Mr. Reinartz' flowing interpretation of the progress made in the last one hundred years is being presented in a series of four articles.

by Leo F. Reinartz

(Next month: early working conditions and hazards, the use of hot metals, and the development of new processes and furnaces in the steelmaking industry.)

THIS is the Age of Steel. We live in a mechanized era. Our everyday lives—everything we see or do—are organized and influenced by this versatile metal. Our industries, our farms, our homes, and our transportation—yes, our vocations and avocations, or luxuries and necessities—all are dependent upon smelting iron and making steel. Take away iron and steel and soon our vaunted civilization would revert to a primitive existence.

These metals, often in crude forms, have been known for thousands of years. Down through the ages, until about one hundred years ago, steel was made laboriously, and at high cost, in small batches. During those years, methods of manufacture did not change very much. Over long periods of time only warriors, royalty, and wealthy people could afford to use articles made of iron or steel.

History has recorded that the nations which were expert in iron and steel manufacture, and had access to rich iron-ore deposits, were the leaders in war or in peaceful pursuits.

LEO F. REINARTZ is a consultant with the Armco Steel Corp., Middletown, Ohio.

At the end of the 18th century, thirteen struggling American colonies had broken not only the political shackles that bound them to Great Britain, but also many of the economic bonds. They had showed their skill, Yankee ingenuity, and energy by making iron and steel articles for their own use.

After the Revolutionary War, more and more hardy American pioneers pushed westward through the Allegheny Mountain passes and down the rivers into the fertile Ohio River and Kentucky country. Demands for articles made of iron increased. The iron industry on the east coast grew and prospered.

As this trend continued, iron industrialists moved their plants westward to be near the large deposits of high-grade coal in western Pennsylvania, eastern Ohio, and nothern West Virginia. They also desired to use the local iron ores and water resources of those areas. Blast furnaces and ironworks were built in the Pittsburgh, Youngstown, southern Ohio, and northern West Virginia districts.

In 1810, the United States produced 53,908 gross tons of cast iron and 917 tons of steel.

Iron ore discovery

A white man first discovered large deposits of iron ore in the northern Michigan and Lake Superior country in 1844. One year later, the Sault Ste. Marie

ship canal was completed, making these easily mined ores accessible to the iron and steel-producing centers south of the Great Lakes.

In 1853, Jones & Laughlin Ltd., a pioneer in steel manufacture, began its operations at Pittsburgh.

It is worthy of note that in 1857, the first of the one hundred years of modern iron and steel industry, a severe commercial depression hit the United States. Its effects were felt by the growing iron and steel industry.

Nevertheless, that year saw the coming of the industry to Chicago. Also during that first year, 26,375 gross tons of iron ore were shipped from Lake Superior iron-ore mines to steel plants. Hard ore could be delivered on Cleveland docks from the Marquette Range in Michigan at a cost of $7 per gross ton. At that time, a sample of Lake Superior iron ore showed the following contents: iron oxide, 98.02 pct; manganese oxide, 1.22 pct; silica, 0.44 pct; calcium oxide, 0.32 pct.

It was only natural that as early as 1857, attempts were made to produce steel directly from such rich ores, but because of deficiencies in process and equipment, the experiments were unsuccessful.

In those days, puddled iron was made in small batches by refining pig iron. The puddled iron blooms could be cut up, piled, reheated, and rolled into rails, shapes, and bars. The latter could then be reheated and rolled into sheets.

High-grade tool and spring steels were made in crucibles in even smaller batches. However, strange to relate, it was the cheapest and best steel made in that period.

Many foundries made cast-iron commodities. In 1857, iron and steel products consisted mostly of boiler plates, bar and sheet iron, nails, rivets, spikes, rails, plow and spring steels, crowbars, sledges, as well as steel and iron castings of many shapes and for many uses.

There were 16 foundries in Pittsburgh. Rolling mills were erected at Niles, Ohio in 1857. The equipment consisted of puddling furnaces and forges, heating furnaces, a train of rolls, and cut nail machines. In this plant, as a rule, workmen's wages were paid in *scrip* which could be exchanged for goods at company stores. The workmen were given one dollar in cash for the Christmas and July 4th holidays.

In the same year, Scioto Rolling Mill Co. was organized at Portsmouth, Ohio. It was a forerunner of the present day Detroit Steel Corp. of that city.

Early plants

It is interesting to note that the Wheeling Steel Corp., of Wheeling, W. Va., traces its early history back to the Principio Co. of Maryland, one of the first iron-producing companies in the US, where a crude furnace was built in 1715.

The St. Louis Stamping Co. was incorporated by William F. and Frederick G. Niedringhaus in 1866. The brothers were thrifty, independent businessmen, who had immigrated from Westphalia in the 1850's. In 1878, they erected the Granite Iron Rolling Mills at St. Louis, Mo. These mills were the forerunners of the Granite City Steel Co., now at Granite City, Ill.

On July 5, 1875, the Joseph H. Brown Iron & Steel Co. was founded on the site of the present Wisconsin Steel Works of the International Harvester Co. It is now the oldest plant in the Calumet steelmaking district of Chicago.

In 1858, labor made the first of many attempts to organize the iron and steel industry in the Pittsburgh area. Workers lost this contest. During the year 1860, the Sons of Vulcan, an organization of puddlers, heaters, roughers, and rollers—the cream of steelworkers—was formed. It played a prominent and, at times, violent part during the next few decades in the strenuous, though unsuccessful, effort to organize the steel industry.

In 1860, James M. Swank reported a production of 821,225 gross tons of pig iron (but only 11,838 tons of steel) in the United States. In the same year, 200 Catalan forges were operating in the southern Ohio and Potomac River districts, and 30,626 miles of railroad rails were laid in the US.

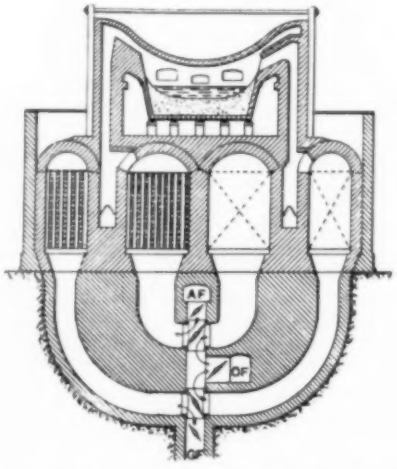
The trek westward

Prior to the Civil War, most Americans lived on small farms or in villages. Many young people became dissatisfied and craved change and excitement. Thus, in the early 1860's and in the years following the War, the great trek west, which had started before the 1849 California gold rush, began to assume tremendous proportions.

In the human avalanche were pioneers who liked "the wide open spaces," adventurers, prospectors, criminals, discouraged persons, and discharged soldiers from the Gray and Blue armies. By the thousands—on horseback, by stagecoach, and by covered wagon—they traveled from the great Mississippi and Missouri Rivers across the central plains. Some stayed in this vast area to farm or to raise cattle; almost overnight, villages and towns sprang up.

Other restless, adventurous spirits relentlessly pushed on to the Rocky Mountains seeking fortunes through prospecting and mining. Many hardy souls continued, despite terrible hardships, until they reached the fertile valleys of the Pacific Coast. Here they joined with those who, years before, had come to this wonderful country by ocean travel from the eastern states, or from Mexico and other foreign countries.

Demands for equipment and supplies to outfit these modern *nomads* were enormous. Even when they had settled down to farm, raise cattle, mine, or engage in commercial pursuits, the itinerant ped-



Section of Siemens steel melting furnace showing arrangement of regenerators, flues, and valves. AF is air flue, CF is chimney flue, and GF is gas flue.

dlers, pony express, and stagecoaches were often too slow and uncertain to bring their necessities—many of them iron and steel articles—from the industrial east. In addition, the population of the industrial middle west was rising, increasing the demand for steel products.

The resulting clamor acted as an incentive for industrialists and manufacturers to move their plants westward. This move, in turn, necessitated prompt delivery of raw materials.

The bessemer process

The stage was now set for the exploitation of a more dependable, faster, and cheaper method of transportation. The railroads were looking for a process to make rails rapidly and cheaply.

William Kelly decarburized molten iron by the use of an air blast, at Eddyville, Ky., in 1850. At that time he was merely trying to burn out carbon and silicon. In 1856, when Kelly heard that Henry Bessemer had filed a patent in England on a similar idea, he filed an American patent. During the next ten or more years, considerable litigation took place before the two men merged their interests.

To this day, possibly because of the prominence of the English inventor (he was knighted by Queen Victoria) this method for making steel pneumatically is known world-wide as the bessemer process.

Sir Henry Bessemer was successful in making commercial steel because the ores used in his experiments happened to contain a considerable amount of manganese and a low sulfur content. However, if Robert Mushet, another Englishman, had not developed spiegeleisen, an alloy of iron and manganese, and used it for deoxidizing and recarburizing the blown bessemer metal, that process would have had only limited commercial value.

The invention of the bessemer process was one of the outstanding milestones in the steel industry and in human history. It marked the breaking away from age-old, slow, tedious, costly processes of making steel. Whereas puddled iron could be made in lots of less than 500 lb in 3 to 5 hr by dint of hot, heavy work, the new process could make steel in 5-ton lots with much less labor in less than ½ hr. It was more uniform and of better quality than its predecessor.

From 1867 on, the adoption and improvement of the bessemer process was rapid. It made possible the "winning of the West." Structural shapes could now furnish strength and economy to build steel skyscrapers; streams—large and small—could be be bridged; steel ships replaced wooden windjammers; steel could be used to build machinery and equipment for modern factories.

Because steel could be produced cheaply and rapidly by the bessemer process, this method of making steel was in its heyday. As more and more plants installed new converters, the sky glowed with their sparks, flames, and dense brown fumes day and night. *Kish* from blast furnaces, brown deposits from bessemers, and black smoke from the combustion of coal were signs of prosperity and wealth. When the air was clear in steel communities, it was the sign of a strike or a business recession, and no pay checks. Since most steelworkers lived from hand to mouth, such occurrences were calamitous.

The years from 1870 to 1900 witnessed the greatest expansion of steel manufacturing and railroad building in the United States the world has ever seen. More than 500,000 miles of rails were laid between 1865 and 1885. By 1890 this country had become the leading steel-producing nation in the world. The bessemer process accounted for 6,685,000 gross tons of ingots in 1900, while its younger rival, the Siemens-Martin process (see below), could muster only 3,404,000 gross tons.

The narrowing down of the bessemer process preeminence was due to its "Achilles' heel." It could make steel for pipe, rails, wire, and common varieties of sheet steel, but because of the high nitrogen, sulfur, and phosphorus contents, steel made by this process could not be used to produce high-quality, deep-drawing sheet and other specialty steels. Furthermore, manufacturing depended on hot metal made from iron ores, not readily available and decreasing in quantity. In the bessemer process only limited amounts of scrap iron could be melted.

The Siemens-Martin process

During the early days of the industrial era, large tonnages of scrap iron began to accumulate. It came from steel plant operations, fabricating shops, and wornout, damaged, or obsolete steel products from the railroads, farms, homes, and elsewhere. Scrap iron, therefore, became a drug on the market. Huge piles of cheap scrap iron, as well as the success of the bessemer process, attracted and stimulated the minds of many inventors.

In the early 1860's, Sir William Siemens, a German-born English citizen, had invented the regenerative principle for heating materials to high temperatures. In 1862, he had built his first regenerative furnace in England. By 1868, he had developed a pig-iron and iron-ore method for making steel on a sand bottom, using this regenerative idea for heating.

The practice of charging scrap iron to dilute the pig-iron impurities—in place of Siemen's pig and ore process—was developed by Emile and Pierre Martin in France. This process now could make use of the large scrap-iron inventories. The duration of heats could be decreased because less time was required to decarburize the molten bath.

This method for making steel soon began to be known as the Siemens-Martin open-hearth process. Its development was painfully slow. In 1868, a small furnace was built at Trenton, N. J., but after a short period of experimentation, it was abandoned.

The first successful regenerative steel-melting furnace was built in South Boston, Mass., in 1870. It was a tiny, 5-ton furnace, very crude when compared with present day, modern, open-hearth giants. Since silica brick were as yet not available, fireclay brick were used to build this furnace on ground level.

The furnace had multiple uptakes and downtakes, no slag pockets, and an acid-lined hearth. Direction of the flame was helped by a roof depressed at the center. Regenerative chambers, located directly under each end of the furnace, were rapidly clogged with slag, a condition that did not change until Siemens, in 1877, patented his idea for placing the chambers under the charging floor. Slag pockets were then put under each end of the furnace. Since those early days, furnace design has not changed a great deal.

Generally, producer gas was used as an open-hearth fuel. The manufacture of artificial gas was in its infancy in the US and left much to be desired for such a purpose.

Early furnaces were charged manually through a charging door by means of long handled peels. The charge consisted of a mixture of puddle bars,

scrap iron, and English hematite pig iron. The day when hot metal would be poured into a furnace was still distant. Approximately eight hours were required to make a heat. The metal was then removed from the furnace through a tapping hole and spout located opposite the charging side, and run off into a brick-lined container equipped with a nozzle and stopper rod. It was then teemed into molds situated below the container.

In October 1874, two 7-ton acid open-hearth furnaces were started at the Otis Steel Co. in Cleveland. Two 15-ton furnaces were added in 1878, and two more of the same size went into operation in 1881 and also in 1887. This was the first company in the US to depend exclusively on open-hearth steel.

The furnaces were built 10 ft above ground level. The charge was raised to the charging floor by a hydraulic lift. Each heat was tapped into a ladle hung on a hydraulic jib crane. To teem the metal, the ladle was swung around over a short drag of molds. This operation, preceding the day of electric cranes, was a great advance in steel production.

The general use of acid open-hearth steel in the United States was short-lived. This process, though it could use large quantities of scrap iron, was similar to the bessemer process in that sulfur and phosphorous could not be eliminated from the molten metal.

Basic open-hearth shops

The first basic steel was made experimentally on May 24, 1884, in a bessemer converter at the Pennsylvania Steel Co., Steelton, Pa.

In 1886, the bottom of one 15-ton furnace at Otis was lined with basic magnesite imported from Austria. It was fritted in with heat, and slag was melted on the bottom to fill up the voids. After a 4-month trial, the bottom was changed back to acid construction.

The idea of using a basic hearth bottom by means of which the sulfur and phosphorus content of the metal could be controlled was sound. Thus, the basic open-hearth process, as we know it today, was given its greatest impetus when Carnegie, Phipps & Co. Ltd. built fifteen 35-ton furnaces with basic hearth bottoms at the Homestead Works, Munhall, Pa. The first heat was tapped on March 28, 1888.

These furnaces were built on the ground. Checker chambers were below ground level, under the charging floor, between the furnace and the stack. Natural gas, found in abundance nearby, was used as a fuel. Only the air for combustion was preheated. The furnace was reversed by means of cast-iron butterfly valves. The hearth was cylindrical, having an area of 176 sq ft. Tar-impregnated dolomite was used to frit in the first bottoms.

In a few years, the company changed most of its hearths to a rectangular design. A few round furnaces with removable roofs were kept for many years to melt large chunks of scrap iron, spills, and other irregular pieces from all the corporation plants.

The No. 2 shop was built in 1890. It contained eight 47-ton basic open-hearth furnaces. The last eight furnaces were installed in 1901.

No. 3 shop was started in 1898 and finished in 1899. It contained 24 furnaces under one roof, all of which were built on ground level. Checker chambers, valves, and open-hearth pits were below ground level.

The first two-level shop at Homestead was started in 1906, when 10 furnaces were built. It was completed in 1910 with the erection of four more furnaces.

Hot metal was first used in the open-hearth furnaces at the Homestead Works about 1900.

During its first 50-year history, the open-hearth process seemed to have more than its share of difficulties. The work was hard, hot, and dangerous. Furnace operators and maintenance men labored long hours on two shifts: 11 hr in the day and 13 hr in the night, with a grueling 24-hr shift at the end of every second week, when crews changed over from day to night work.

In those days, American boys were not interested in working in the scrap yard, the open-hearth pit, or on the labor gang. A few asked for jobs on the open-hearth charging floor because they were attracted by the relatively high wages of first helpers and melters.

Melters were jealous of their jobs and prerogatives. Novices often had to pay them for the privilege of learning a furnace job. It was rumored that sometimes new furnace men paid as much as $250 for this privilege.

The melter usually drew the pay for his entire crew. He then distributed the money as he saw fit. Naturally, irregularities and favoritism crept in. Later, this practice came to haunt management, when workers began to rebel against unfair practices. Those were the days when cocky steel-mill melters and rollers came to work carrying large rolls of bills or cash in special money belts, which they loved to exhibit to their underlings.

Foreign workmen

The hot, dirty jobs of the open-hearth shop were done by foreigners—men with strong backs from the undeveloped countries of southeastern Europe. Most of them, in the early years, did not speak English. They had to be given orders in sign language or by means of fluent, though vulgar, Anglo-Saxon words from none-too-gentle American straw bosses, as labor foremen were known in those days.

In the late 1890's and in the early years of the 20th century, thousands of foreigners came to America and worked in steel plants. Usually they were brought to this country by sponsors, sometimes referred to as "padrones." At the steel plants, foreigners were housed and fed in cheap, none-too-sanitary boarding or bunk houses. A heavy price in the form of kickbacks from their low wages was exacted from these foreigners for repayment of their passage fare and for their keep.

As time went on, progressive steel plant managements eliminated many of these abuses. More livable quarters were provided. Classes in Americanization and English were started.

Foreigners, as a class, were thrifty. Many saved enough to bring their wives and families from the old country. In some steel towns, foreigners bought homes away from the sections where former language, customs, and prejudices were still in vogue. Their children went to school with Americans. These people became substantial citizens of the communities in which they lived.

The steel industry owes much to these unsung, humble, hard-working pioneers. Their sons, grandsons, and even granddaughters are often the backbone of present day steel organizations. Some descendants manage the plants where their elders toiled as laborers.

ELECTRIC DIRECT-REDUCTION PROCESS

Produces Steel or Pig Iron

Here is another new steelmaking process. It makes use of a double-hearth, low-frequency induction furnace for the production of pig iron or steel. It can produce high-quality and alloy steels.

by Albert de Sy

ALBERT DE SY is the head of the Metallurgical Dept., University of Ghent, Belgium. This paper is being presented at the 1959 Blast Furnace, Coke Oven, and Raw Materials Conference.

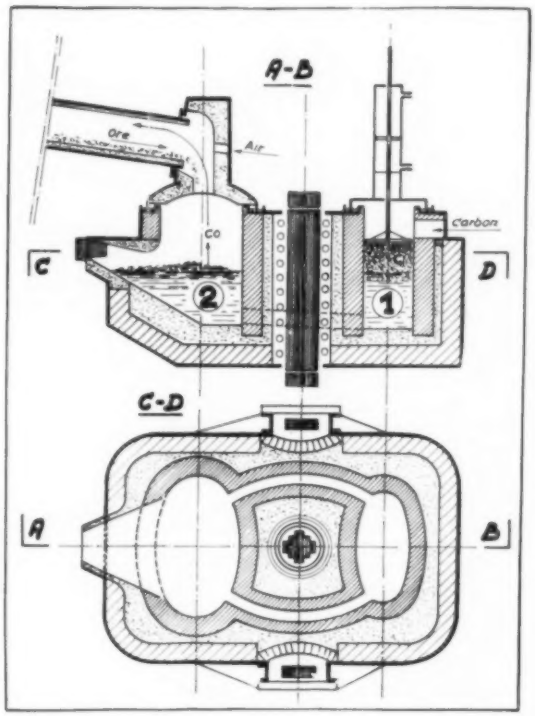


Fig. 1—Schematic drawing of the 1-ton, 150 kva, double-hearth, low-frequency induction furnace.

In recent years a great many new iron-reduction processes have been announced, and some of them are now being tried out on a pilot-plant scale. Reducing agents and energy sources employed by such processes vary over a wide range. The products obtained vary from sponge iron and low-carbon, high-purity iron to liquid steel and liquid pig iron.

At this stage, a comparison of the technical and economical value of these different processes is difficult if not impossible, because only a few are really operated on an industrial scale, and even then only in especially favorable local circumstances regarding raw materials and/or energy supplies. However, all these new processes have common trends: the use of a reducant other than normal blast-furnace coke, a separate energy supply, and the use of high-grade ores or concentrates.

The process dealt with in this article is an electric direct-reduction process which produces either liquid steel of the rimming type or a carbon-rich alloy of the pig-iron type. It needs a special high-grade iron ore, a fairly pure carbon as reductant, and electricity as the main source of energy.

Principles of the process

The process is operated in a double-hearth, network frequency induction furnace and, consequently, the process must be continuous. Both the principle of the process and the special furnace design are illustrated by Fig. 1, which is a schematic drawing of the 1-ton, 150-kva furnace installed in the melting shop at the author's laboratory.

The furnace itself is an electric transformer, consisting of a water-cooled primary coil with an iron core and the metal bath as a single secondary winding. This metal bath is contained in two hearths with separate surfaces but connected at the bottom level by means of arched ducts.

The energy input is regulated in nine steps by controlling the voltage applied to the primary coil; it may vary from a few kw to a maximum of 135 kw for the pilot furnace. Another very important feature is the stirring action in the metal bath; this should not be too violent, but it must be intense. The problem of regulating the intensity of the electromagnetic stirring has been perfectly solved by Forni Elettrici A. Tagliaferri, Milano, Italy, who built the author's furnace.

The process itself is characterized by two essentially different, but simultaneous, phases: carburization of the liquid iron bath in hearth No. 1 and decarburization or iron-oxide reduction in hearth No. 2.

Hearth No. 1 operates under strongly reducing conditions with a large carbon excess lying on the metal surface and partially submerged in the liquid iron by means of a plunger. Instead of carbon, a mixture of carbon and dry lime powder or any other desulfurizing mixture may be used in order to prevent, or at least limit, sulfur pickup. Although this has not yet been extensively explored, it is believed to be efficient because the desulfurizing conditions are ideal (especially with the correct metal bath stirring intensity).

Operating at 2700° to 2800°F seems to be the optimum range, since the carbon dissolved in hearth No. 1 rapidly migrates to hearth No. 2. This is due mainly to the stirring action, because diffusion alone would result in a very high carbon gradient between the two hearths. In practical operation, a carbon content of 4 pct in hearth No. 1 corresponds to approximately 3.8 pct C in hearth No. 2; this low carbon gradient is, of course, very important.

Ore additions, either cold, preheated, or preheated and prereduced are made to hearth No. 2. They melt on the metal surface and react with the dissolved carbon to produce iron and carbon monoxide.

With a good stirring action and satisfactory metal fluidity, corresponding to an iron bath of 2700° to 2800°F and 3 to 5 pct C, the reaction is very fast, and results in a violent boiling corresponding to a carbon elimination of some 4 pct C per hr (when the 1-ton furnace contains 500 to 600 kg of metal); this is 10 times faster than the normal boiling reaction in the open-hearth furnace.

Iron production is, of course, proportional to carbon consumption, and the furnace is filled progressively. On tapping, some 300 to 350 kg of metal (or 25 to 30 pct) should stay in the furnace, and the process is repeated.

First experimental results

In March 1958 we ran the first campaign during 5 days and 4 nights, making pig iron with 4 pct C and 0.8 to 0.9 pct C tool steel. The furnace was hand operated, and the two hearths had equal surfaces. The ore was introduced through a small hopper in lumps of approximately 1 in. The carbon monoxide gas produced was evacuated directly to a chimney where it was burned. The depression in hearth No. 2 was measured by a liquid column manometer attached to the ore-feeding hopper. Since then the furnace has been modified by changing the surface ratio of the hearths approximately as appears in Fig. 1, and by adapting a small rotary kiln for continuous feeding of preheated ore as shown in Fig. 2.

The ore used was the very rich Brizilian Itabira lump ore of the following composition: 69 pct Fe, 1 to 1.5 pct gangue, 0.035 pct P, and 0.008 pct S; charcoal was employed as the reductant. At the start of the steelmaking process, the furnace contained 450 kg of liquid pig iron from the previous heat; it had the following composition: 4.45 pct C, 0.18 pct Mn, 0.055 pct P, and 0.011 pct S. During the steelmaking operation 725 kg of Itabira ore was charged and reduced in exactly 10 hr; this corresponds to an average production rate of 50 kg of iron per hr. Carbon consumption amounted exactly to the stochiometric quantity, since there were no carbon losses.

Energy input varied between the extreme limits of 40 and 135 kw, corresponding to 280 to 540 v on the primary coil. The total power consumption was 905 kw-hr, corresponding to 1810 kw-hr per ton and an average input of 90 kw, which is some 5 pct more than the level of operation for at least 90 pct of the total time of 10 hr. The furnace then contained 950 kg of pig iron at 2790°F and approximately 4 pct C.

Since the aim of this particular operation was to make tool steel containing 0.8 to 1.0 pct C, and less than 0.03 pct Si, 0.35 pct Mn, 0.025 pct S, and 0.025 pct P, the process went on without any further carbon additions except ore additions to hearth No. 2. The temperature was raised progressively up to 2980°F. Final temperature and composition were reached after 2½ hr, which is 1 hr too much for normal practice.

The steel was tapped at 2965°F, and as it contained no silicon and only about 0.15 pct Mn, it was boiling heavily. It was intended to tap 650 kg, but because of the heavy boiling, only about 550 kg was tapped. Ladle additions were as follows: 0.3 pct Mn, 0.3 pct Si, and 150 g of Al. After pouring, several very small ingots, a hot-top ingot of 300 kg was poured but a second one was not completely filled because of insufficient metal. The larger ingot, which weighed 312 kg, was rolled without difficulty into billets measuring 3¼x3¼ in.

The final steel composition was as follows: 0.85 pct C, 0.23 pct Si, 0.42 pct Mn, 0.012 pct S, and 0.065 pct P. No attempt was made to dephosphorize the metal. The quality was normal for this type of tool steel, and the inclusions corresponded to ASTM No. 1.

Furnace lining

In hearth No. 2 the lining is exposed to the strongly oxidizing iron-oxide slag; therefore, the lining must be basic. It is believed that hard magnesite brick for the side walls and channels, and a magnesite ramming mix for the bottom of the hearths represents the best solution. Behind this first layer is a plastic ramming mix of basic nature, and insulating brick and an asbestos sheet are against the outer steel plate. This gives a fairly thick lining, but for an industrial-scale furnace the total lining should be much thicker. This is perfectly allowable without adversely influencing the current yield; in fact, this thick lining constitutes the great advantage of the network frequency channel-type furnace compared to the high-frequency induction furnace.

After the first campaign, and even now, there has been no lining wear in hearth No. 1 and in the ducts. At one level in hearth No. 2, lining wear was ½ in. deep after the first campaign, but it is believed that this was due to the melting of the acid roof, heated accidentally by the combustion of carbon monoxide

at one time when air came in through the iron-ore charging hopper.

Of course, if the iron-ore gangue is acid, lime additions are necessay. If this precaution is taken, and since the slag remains relatively cold—being heated only indirectly through the intermediary of the metal—it is believed that lining wear may be kept within reasonable limits.

Raw materials

This new process is suitable for very rich ores only. If, as usual, the gangue is fairly acid and consequently necessitates basic additions, 67 to 68 pct Fe should be considered as the lower limit.

The reductant should also be rich in carbon, and low in ash and sulfur. Charcoal and graphite are, of course, ideal, but they are generally too expensive. Carbon-rich anthracites seem to represent the best industrial solution. Here again the acid ash should be neutralized by lime powder additions.

Metallurgical aspects

Desulfurization of the metal after tapping is necessary when the ores are sulfurous and/or when the reductant contains sulfur and no attempt is made to desulfurize or to prevent sulfur pickup.

When operating with a high carbon content during the reduction period, which is desirable for many reasons, dephosphorization is impossible; on the contrary, phosphorous pentoxide from the ore is reduced.

However dephosphorization is possible at the end of the refining period either in the furnace or by duplexing. There are two reasons for preferring the latter: 1) the reduction furnace may be operated at a constant temperature, while increased temperatures are necessary if refining is done in the same furnace, and 2) since 25 to 30 pct of the charge must be kept in the furnace to start the following reduction period, the refining of that part of the metal is useless; even worse, carbon must again be added to attain the ideal 4 pct C level.

The slag layer remains relatively cold, and oxides other than P_2O_5 and FeO are not substantially reduced, except of course NiO, Cu_2O, and others, if they are present in the ore; MnO is reduced to a very small extent, while TiO_2, SiO_2, and others are absolutely not reduced.

Prereduction

When operating with cold hematite ore, some 600 normal cu m of carbon monoxide is produced per metric ton of iron; this corresponds to an energy of over 2 million kcal. The first idea that arises is to make use of this energy for preheating and prereduction of the ore charge. The economical aspects of this will be considered later in this paper, but there is also a purely technical advantage of charging a prereduced ore.

After introduction of a charge, the slag remains solid or at least very sticky for some time, even when the slag temperature becomes normal. This is a matter of slag composition and not of slag temperature. Indeed, the melting temperatures of Fe_2O_3 and Fe_3O_4 exceed 2700°F, while normal slag temperature is about 2640°F. Thus, the slag becomes fluid as soon as the compounds Fe_2O_3-Fe_3O_4 are substantially reduced to FeO. A high reaction rate between the iron oxide slag and the metal is obtained when the electromagnetic stirring realizes an emulsion of

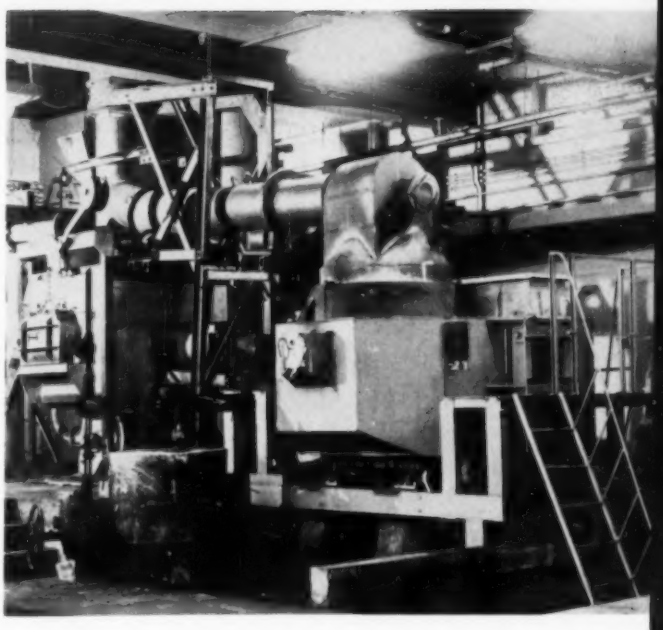
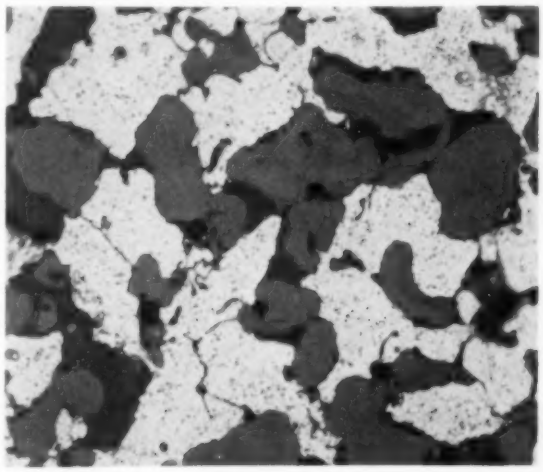


Fig. 2 (above)—The 1-ton pilot furnace with a small rotary prereduction kiln in the author's laboratory. Fig. 3 (below)—Microstructure of 70 to 75 pct reduced sponge from Itabira fines. 750X.



the two reacting phases, but such an intimate emulsion is possible only when both phases have a good fluidity. Thus, it is essential to keep the slag at normal fluidity, which can be achieved when charging FeO instead of other iron oxides.

A first attempt to make use of the energy contained in the carbon monoxide gas produced in hearth No. 2 has been achieved at the pilot-plant scale by adapting a small rotary kiln to the furnace, thus making possible continuous ore feeding in countercurrent with the carbon monoxide. Unfortunately, lack of space in the melting shop at the author's laboratory permitted the installation of a rotary kiln of only 3 m length. This was insufficient for prereduction purposes. But it is well known from the experience with the Basset and Krupp-Renn processes, that even a longer furnace would

Table I. Process Heat Requirements Per Metric Ton of Pig Iron at 2800°F Produced From Cold Hematite

1. Endothermic direct reduction reactions	100,000 kcal
2. Sensible heat of products:	
1 ton iron	340,000 kcal
760 kg CO	335,000 kcal
60 kg slag	25,000 kcal
Total	800,000 kcal

not achieve the desired prereduction, because of insufficiently intimate contact between ore bed and gas phase.

Carbon monoxide gas introduced into the ore bed is rapidly oxidized to a mixture of carbon monoxide and carbon dioxide in equilibrium with the ore unless carbon is present. It is, therefore, essential to mix some carbon with the ore charge in order to keep a reducing atmosphere in the bed.

When adopting the rotary kiln as a preheating and prereduction furnace, ore particle size is of great importance. The ideal ore size is probably the fraction from 20 mesh to 1 in. Anthracite particles, to mix with this ore fraction, should preferably be between $\frac{1}{8}$ and $\frac{3}{8}$ in. Of course these limits are not imperative, but very small particles, although advantageous for a high reduction rate, are carried away as flue dust.

If the charge is available as ore fines or concentrates, it may be advantageous to apply pelletizing followed by an oxidizing-desulfurizing roast either in a separate kiln or in the furnace feeding kiln. In the latter case the first part of the kiln, i.e., the part towards the charging end, should work under strongly oxidizing conditions, while the part towards the discharge end should work under reducing conditions. If pelletizing is difficult or impossible, it is always possible to make agglomerates by pressing a mixture of ore fines and coal pitch.

Experiments on another type of furnace are being conducted on a very small scale. The furnace is a multitubular furnace in which cylindrical agglomerates of ore fines, pitch, and coal are pushed through the tubes and fall into the reduction furnace, while combustion gases circulate countercurrent in the space between the tubes.

By heating such agglomerates in a 2 to 3-hr cycle, reaching 1700° to 1900°F the reduction reaction is complete. Fig. 3 shows the microstructure of such a partially reduced sponge from Itabira fines (−60 mesh); the stage of reduction is 70 to 75 pct, i.e., this percentage of the oxygen has been eliminated. Prereduction stages of 33 pct ($Fe_2O_3 \rightarrow FeO$) to 75 pct are considered ideal, because they correspond to the best economical working conditions of the process.

Table II. Energy Requirements Per Metric Ton of Pig Iron at 2800°F

Charge	Carbon Plus Pitch, Kg	Process Heat, Kcal	Power Consumption, Kw-Hr	
			Pilot Furnace	Industrial Furnace
Cold hematite	350	800,000	1830	1630
33 pct prereduced ore at 1800°F	380	470,000	1010	910
70-75 pct prereduced ore at 1800°F	420	280,000	610	540

Energy requirements

When feeding the pilot double-hearth reduction furnace with cold hematite ore and producing pig iron, energy requirements amount to roughly 1800 kw-hr and 350 kg of carbon per metric ton of iron tapped at approximately 2800°F. For an industrial-scale furnace operating in the same conditions, the power consumption would be approximately 1600 kw-hr. Much more can be done through preheating and prereduction of the charge.

The energy consumption of the new process compares favorably with the 2000 to 2200 kw-hr and comparable carbon consumed in European electric-arc reduction furnaces operating on rich ores. The reason for the difference is simple: induction heating as applied here results in the highest possible calorific current yield, because the heat is generated entirely in the metal bath.

In three different experiments with cold ore charges, and for melting periods of 10 hr, the measured power consumption was 1810, 1885, and 1835 kw-hr per metric ton of pig iron. These figures are in agreement with the results of theoretical calculations.

The process heat requirements shown in Table I are necessarily approximate. Such requirements are, of course, independent of the furnace size. They must be delivered as electrical energy, and the 800,000 kcal shown corresponds to 1030 kw-hr. To maintain the furnace at working temperature without producing, 40 kw-hr is necessary. From this value, and from the average production rate of 50 kg per hr, we learn that the heat losses amount to 800 kw-hr per metric ton, making a total power consumption of 1830 kw-hr.

It is also possible to calculate the effect of various degrees of preheating and prereduction upon the power requirements. The results for 33 pct and 70 to 75 pct prereduction, corresponding respectively to minimum production rates in the pilot furnace of 100 and 160 kg per hr, are presented in Table II.

Duplexing

For the industrial application of this new process up to the stage of steel ingots, it is desirable to use a duplexing operation. There are several possibilities of duplexing, four of which have been alternatively considered in Fig. 4.

The plant shown comprises five reduction furnaces of the type described. Each furnace has a power rating of 1500 kva and a metal capacity of 10 to 12 metric tons. Similar furnaces, but with a single hearth, are in operation for melting cast iron in continuous campaigns of 4 to 6 months before lining repairs become necessary.

Five furnaces have been chosen in relation to the proposed duplexing operation because in two of the alternatives it is intended to refine the pig iron in a single hearth, channel-type induction furnace, and one such furnace is capable of handling the production of the five reduction furnaces. But for very small capacities, one reduction furnace can be coupled with one refining furnace, the latter then having a much lower power rate and metal capacity.

On the flow-sheet, Fig. 4, only one preheating furnace is represented. It is, however, evident that each reduction furnace can have its own prereduction unit or that one large-scale preheating and prereduction furnace may supply the different reduction furnaces through insulated and controlled feeders.

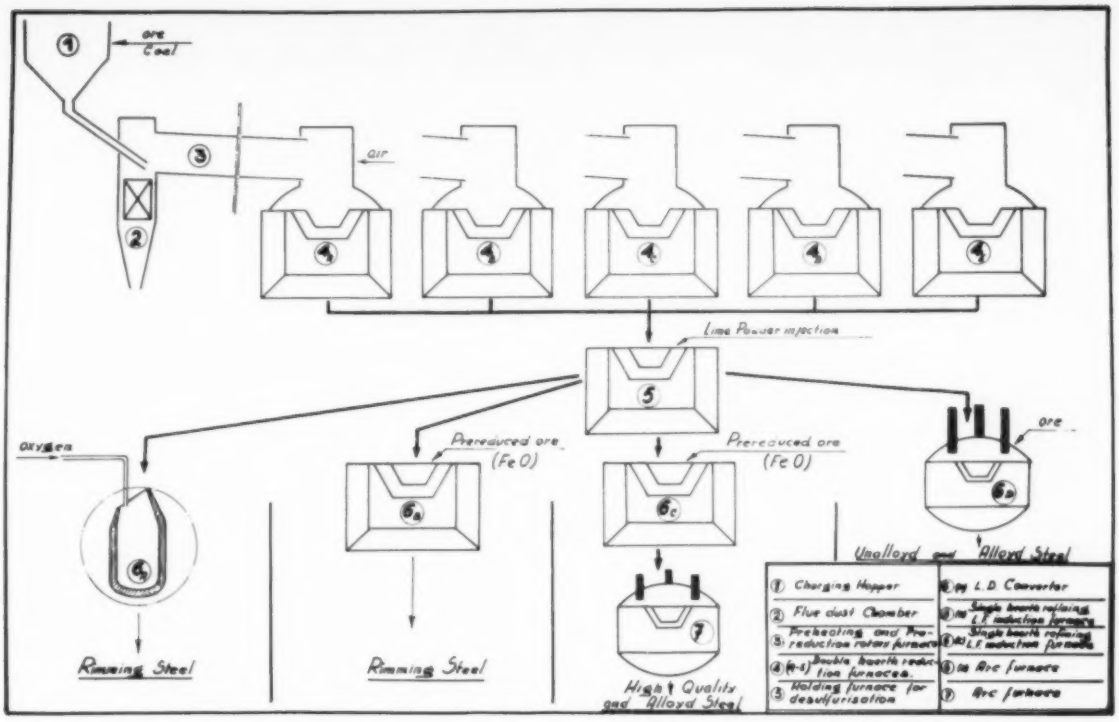


Fig. 4—Schematic representation of an industrial plant capable of producing 80,000 metric tons of steel ingots annually.

Except for very pure raw materials, such as Brazilian ore and charcoal, the pig iron may have a relatively high sulfur content, and in many cases desulfurization may be necessary or desirable. Desulfurization can be done in a holding furnace which, in any case, would be used in many duplexing procedures.

The iron never contains any silicon. If it contains no other exothermic combustion elements such as phosphorus or manganese, it is doubtful that the LD process would work.

Except for high-phosphorous iron, which is unlikely to be produced by the process, the conversion of pig iron may be done in a furnace of the same type as the reduction furnaces, except that it would have one hearth instead of two. Refining would proceed by the normal method of ore additions, preferably prereduced. It is, however, impossible to deoxidize in the furnace or to add alloying elements, except nickel. Thus, only ladle additions are possible.

It is believed that, starting with pure ores, one of the major possibilities of this new process in industrial countries is for the production of high-quality and alloy steels. The iron is indeed produced under very favorable circumstances: low-temperature reduction, absence of hot spots, contact with carbon monoxide atmosphere, and continuous boiling. It may, thus, be expected that nitrogen and hydrogen contents would be exceptionally low. It is for this reason that the flow sheet shows two alternatives for making high-quality and alloy steels with a regular arc furnace as the last production unit. The fourth alternative, however, i.e., refining pig iron with ore additions in an arc furnace, is believed to be less advantageous.

Capital costs

Concerning capital investment for a steel plant capable of producing 80,000 metric tons of steel ingots per year—comprising five reduction furnaces and one of the steel refining lines shown in Fig. 5, it is estimated that the total investment would be approximately 3.2 million dollars or $40 per metric ton per year. Considering that this corresponds to the production of steel ingots and not to some kind of sponge, it is believed that it compares favorably with many other new processes.

It is also worthwhile to point out that the investment costs are nearly proportional to the capacity, because such a plant has several small production units. It is, therefore, possible to apply this process on a very small scale and still with a low investment-per-ton-year.

Conclusions

Although this new process is not intended for tonnage production on the basis of normal ores and in competition with the blast furnace, it is believed that it has a serious chance for successful practical application. With high-grade ores and concentrates available, the requirement that they be used does not appear to be severe. It does, in fact, appear feasible to employ concentrates and produce steel ingots at the mine.

Possible interest of this process for industrial countries is probably limited to the production of high-quality steels in regions producing rich ores and lacking supplies of coking coal.

But the most promising possibilities of this and other new processes exist in industrially underdeveloped countries.

ZINC BLAST-FURNACE OPERATION

The zinc furnace permits treatment of complex zinc-lead ores. Earlier attempts with high CO furnace gas resulted in low thermal efficiency and reduction of iron oxides. The lead splash condenser, developed by Imperial Smelting, has permitted zinc to be condensed from blast-furnace gas high in CO_2.

by S. W. K. Morgan and J. Lumsden

ZINC has been produced commercially in blast furnaces at the Avonmouth works of Imperial Smelting Corp. since 1950. The first production unit to be built had a hearth area at the tuyeres of 55 sq ft. This was followed in 1952 by the construction of a second unit with a hearth area of 69 sq ft. Through intensive development work their capacities have been progressively increased. No. 1 furnace is now producing regularly 45 tons of zinc per day and 22 tons of lead. At the present time, No. 2 furnace is being modified and should come on line again with a daily capacity of 75 tons of zinc and 45 tons of lead. A larger furnace is being built at our Swansea works, which will burn some 106 tons of carbon per day as coke, and is expected to produce 125 tons of zinc and 34 tons of lead per day. This furnace is expected to be in operation at the beginning of 1960. A similiar furnace is being built under license at Noyelles-Godault in France by the Société Minière et Métallurgique de Penarroya.

Description of the furnace

The construction of the furnace built at Avonmouth is shown diagrammatically in Fig. 1.

The lower part of the furnace corresponds in many respects to the standard lead blast furnace, one of the main differences being that the tuyeres project inside the line of the water jackets in the interests of heat economy. For the same reason, the air blast is preheated in alloy-tube preheaters, fired by furnace gas.

Bullion, matte, speiss, and slag are tapped periodically from the bottom of the furnace into a settler where the phases separate. Slag overflows into a granulating launder.

At the top of the furnace, weighed charges of sinter and hot coke are added alternately. The coke is preheated to a temperature of 800°C in a shaft-type furnace, fired by furnace gas. Since the furnace top operates under pressure, a double bell system is used to introduce the charge.

Gases leave the furnace through two offtakes, arranged symmetrically along each long side, and pass immediately into the condensers; these are brick-lined chambers in the bottom of which is a pool of lead. Three vertical, electrically driven rotors are immersed in this pool and create a shower of lead droplets over the whole cross section of the condenser. By disposing the rotors in successive stages with an appropriate lead flow counter-current to the gas stream, the gases leaving the furnace are rapidly chilled below 600°C and further cooled to 450°C before they leave the condenser. The degree of shock chilling is so great that the majority of the zinc vapor in the gas condenses either directly into solution in the lead or forms liquid zinc which dissolves immediately in the lead. The uncondensed zinc in the gas leaving the condenser is reduced to less than 5 pct of the total entering the condenser.

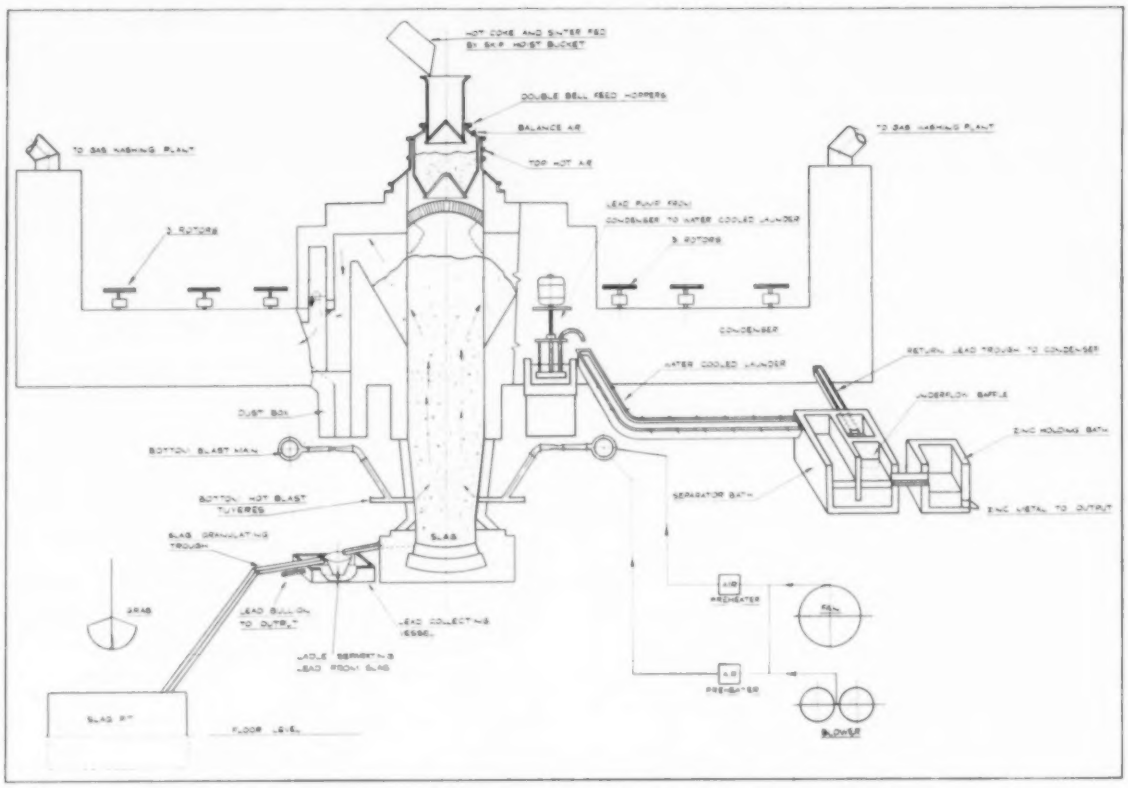
Molten lead now containing zinc in solution at a temperature of 560°C is withdrawn from the end of the condensers nearest to the furnace. It is pumped up into a system of water-cooled launders where its temperature is reduced to 450°C. During this drop in temperature the solubility of zinc in lead decreases, and zinc comes out of solution to float upon the molten lead. The flow is continued into a settling bath where the zinc collects as a layer above the lead and overflows into a holding bath from which it is tapped after treatment with sodium to remove arsenic. The lead, now saturated with zinc at 450°C, passes under a weir (to retain the zinc) back into the other end of the condensers. It is then sprayed into the gas stream by the rotors, and gains in temperature and zinc content again as it passes back through the condenser to repeat the cycle.

The gas leaving the condensers, now stripped of most of its zinc content, is further scrubbed, first in a spray tower and then in a Theissen-type disintegrator. The clean gas with a calorific value of 70 Btu per cu ft is used to preheat the air and coke used by the furnace. The remainder of the gas is used to fire low-temperature furnaces on the site, and the surplus is burned under boilers from steam generation.

Comparison with lead and iron blast-furnace operation

In the zinc blast furnace, as in other metallugical blast funaces, the energy required for reducing a metal from its oxide and for melting the gangue and coke ash, is provided by burning carbon in the air blast at the tuyeres. Some of the monoxide in the

S. W. K. MORGAN and J. LUMSDEN are with the Imperial Smelting Corp. Ltd., Avonmouth, England. This paper was presented at the 1959 AIME Annual Meeting in San Francisco.



Schematic diagram of the zinc blast furnace of Imperial Smelting Corp. at Avonmouth, England.

hot gases thus generated is used to reduce metal oxides as the gases pass up the shaft.

The demands made upon a zinc blast furnace are different and, it may be argued, more stringent than for the other major metals. One difference, for instance, is that the zinc metal is produced as a vapor. Since the furnace can, and in practice usually does, produce lead as well as zinc, the conditions of operation necessarily have some resemblance to those of a lead blast furnace; this resemblance, however, applies rather to the operation carried out than to the physical chemistry of the process, for the liberation of zinc from zinc oxide requires far more drastic reducing conditions than are necessary or desirable when lead is the only metal being produced. The joint lead-zinc smelting depends upon the fact that gases generated to effect zinc elimination are so reducing that they are able to take the lead reduction in their stride. On the other hand, although the furnace is operated so as to ensure that no significant reduction to iron metal takes place, the physical chemistry bears some resemblance to that of iron smelting, for the CO_2:CO ratio in the furnace gases is similar. Under some conditions, as in retort smelting, iron oxide is reduced before zinc oxide; in the blast furnace the conditions are such that zinc oxide is reduced first, but to obtain good zinc elimination it is necessary to have conditions that are almost reducing to iron oxide.

Thus, while there are points of similarity between both iron and lead blast-furnaces practice, the analogy with either is not close, and some of the differences are fundamental. The conditions necessary for good zinc blast-furnace practice are summarized in the following sections.

Fuel requirement of process

Prior to our work at Avonmouth, previous proposals for smelting zinc in a blast furnace had aimed to produce a gas containing carbon monoxide and very little carbon dioxide in order to simplify the condensation problem. Burning carbon to carbon monoxide alone utilizes only a fraction of the calorific value of the carbon. Since the gases have to leave the charge at a high temperature, the effectively available heat from combustion to carbon monoxide after allowing for heat losses from the furnace is so small, in relation to the large amounts of heat required to decompose zinc oxide into zinc vapor and oxygen, that even with preheated air blast the ratio of carbon used to zinc reduced is so high as to make the process quite unattractive.

There is a further reason against this policy. In most zinc ores, iron is a large component of the gangue. Were a zinc blast furnace run so as to produce a gas of low carbon dioxide content, the iron would be reduced to metal. Under very strong reducing conditions, as in the iron blast furnace, the reduced iron would alloy with carbon for the production of a cast iron. If conditions were somewhat less reducing, metallic iron of low carbon content and, therefore, of too high a melting point to be tapped from the furnace, would be produced, and the process would not operate. Thus, if a policy to avoid carbon dioxide in the furnace gas is chosen, in order to carburize the iron, conditions so extremely reducing would have to be provided that the carbon: zinc ratio required in the charge would make the process quite uneconomical.

An alternate policy permitted by the ability of the lead splash condenser to condense zinc from gases high in carbon dioxide content, is feasible and much more attractive. This is the one that was chosen.

Advantages of lead splash condenser

With previously known types of zinc condensers it was impossible to condense zinc from a gas containing appreciable amounts of carbon dioxide. The great advantage of the lead splash condenser is that it enables zinc to be condensed from a gas containing only a small amount of zinc vapor and a considerable proportion of carbon dioxide. The efficiency of this condenser can still be maintained at a high level, even with a high CO_2:CO ratio in the gas. Satisfactory zinc elimination and condensation has been obtained even when the gas leaving the condenser contains 16 pct CO_2 and 12 pct CO. Under such conditions however, it is difficult to avoid some deposition of zinc oxide (by reversal of reaction [1]) on the walls of the flue leading from the furnace to the condenser. For this reason, it becomes more difficult to operate with more than 14 pct CO_2 in the condenser gas.

The ability to condense gases satisfactorily with so high a carbon dioxide content permits a reasonably low fuel:zinc ratio to be used. If the material charged to the furnace consists of sintered high-grade concentrates, it is possible to reduce about 1.1 tons zinc per 1 ton of carbon consumed.

With such a ratio, 5.0 g-atoms of carbon are used per g-atom of zinc reduced. If the condenser gas contains 12.0 pct CO_2 and 19.5 pct CO ($CO+CO_2$ = 31.5 pct), 100 volumes of the gas must have been associated with (31.5/5.0) 6.3 volumes of zinc vapor. Under these conditions the gas entering the condenser contains 5.9 pct Zn, 11.3 pct CO_2, and 18.3 pct CO.

Reduction reaction

The reduction of zinc oxide by carbon is a reversible reaction,

$$ZnO\ (slag) + CO\ (g) = Zn\ (g) + CO_2\ (g) \quad [1]$$

Reaction [1] is endothemic, and its equilibrium constant, therefore rises with temperature. A gas of the composition mentioned is stable only at temperatures at which the equilibrium constant (K) is greater than

$$\frac{0.059 \times 0.113}{0.183} = 0.037$$

K = 0.037 at about 1010°C.

This equilibrium temperature means that if the temperature of the gases falls below 1010°C, the zinc vapor tends to react with carbon dioxide to produce zinc oxide and carbon dioxide. This reversion can be avoided if the gases are maintained above this temperature during their passage to the condenser.

Mechanism of reduction

The reduction of zinc oxide by carbon monoxide, unlike the reduction of iron oxide, is highly endothermic, there being a heat absorption of 45 kcal per mole in reaction [1]. Consequently if, analogously to the main mechanism of reduction in an iron blast furnace, the zinc oxide were all to be reduced with simultaneous heating of the descending charge by the counter-current action of the gases passing up the furnace shaft, the extent to which zinc oxide can be reduced in any temperature interval is limited by the excess of the heat capacity of the ascending gas over that of the descending solids. With a typical charge, this implies that one mole of gas can effect the reduction of 0.01 mole of zinc oxide while its temperature falls by about 80°C. To obtain 5.9 pct Zn in the gas would, therefore, require a temperature drop of (5.9 × 80) 470°C, so that the gas would have to be initially at (1010 + 470) 1480°C in order to effect all the reduction of zinc oxide by counter-current action in the shaft. It is, of course, not feasible to operate the furnace bottom so that the gases leave at such a high temperature as 1480°C. Apart from any other considerations, it would be impossible to generate in presence of coke at 1480°C, a gas that would not be reducing to iron. It is, therefore, impossible to operate the zinc blast furnace with a zinc:carbon ratio so as to effect all the reduction of zinc oxide by counter-current reaction with the upward flowing gases in the furnace shaft.

To avoid iron reduction it is necessary to generate, in the tuyere zone, a gas containing a considerable amount of carbon dioxide. To obtain the most favorable heat balance for the furnace as a whole it is necessary, as in the iron blast furnace, to utilize the calorific value of the furnace gas to preheat the air blast. In an iron blast furnace, the combustion of the carbon to carbon monoxide is sufficient for the work that has to be done at the tuyere zone—melting slag and iron metal. In a zinc blast furnace, owing to the greater heat generated per unit of carbon (due to the partial combustion to carbon dioxide), it is clear that once conditions have been determined to give satisfactory heat balance for the furnace as a whole, there must be provided a considerable amount of endothermic reaction in the form of reduction of zinc oxide in the tuyere zone.

In the tuyere zone there is a slag containing some zinc oxide and a gas with a certain CO_2:CO ratio. The controlling equilibrium in this zone will then be that of the reaction

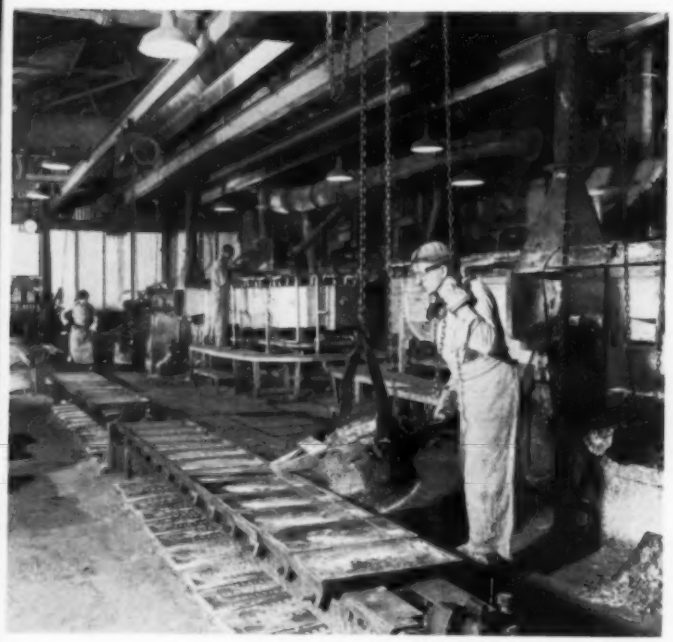
$$ZnO(slag) + CO(g) = Zn(g) + CO_2(g) \quad [2]$$

$$\frac{(Zn)\ (CO_2)}{(CO)} = Ka_{ZnO}$$

where K is the equilibrium constant of reaction [1].

This equilibrium constant rises with temperature; therefore, the higher the temperature in the tuyere zone, the lower will be the activity of zinc oxide in the slag. Once the slag is sufficiently molten to run away freely, it will no longer stay in the tuyere zone but will run down into the slag pool. The temperature of the slag in the tuyere zone is, therefore, related to the melting point of the slag. To obtain good zinc elimination, it is desirable to have a slag of high melting point. It is desirable also to have a slag with a high activity coefficient of zinc oxide so that a given activity means a relatively low content of zinc oxide. By thus controlling the slag composition, it is possible to obtain a good zinc elimination with a high CO_2:CO ratio in the gas.

In practice, slags with a melting point of about 1250°C are used. This may mean that the effective temperature of the gas leaving the tuyere zone is about 1300°C. If this gas can continue to reduce



Casting zinc from No. 1 blast furnace at Avonmouth.

zinc oxide down to a temperature of 980°C then, according to the estimate previously given (320/80), 4 pct by volume of zinc could be reduced by carbon monoxide at the expense of the sensible heat of the gas. However, this reduction (equation [1]) is not the only endothermic reaction taking place. There is certainly some reaction between carbon dioxide and carbon,

$$CO_2 + C = 2CO. \qquad [3]$$

The extent to which reaction [3] occurs is difficult to determine, but studies of the rate of this reaction indicate that perhaps 1.5 pct by volume of carbon dioxide reacts in this way. This leaves available sufficient heat for producing only 2.5 pct by volume of zinc by shaft reduction. If, for example, the gas leaving the charge contains 5.9 pct Zn, 11.3 pct CO_2, and 18.3 pct CO, this means that about 40 pct of the zinc oxide is reduced in the shaft, leaving 60 pct to be reduced in the tuyere zone. It further means that the gas leaving the tuyere zone would have the composition 3.5 pct Zn, 10.7 pct CO_2, and 18.5 pct CO.

This gives a CO_2:CO ratio of 0.57. At 1250°C the equilibrium ratio for the reduction of iron from wüstite is 0.31.

A gas of such composition would not reduce metallic iron from the slag even if the activity (a) of ferrous iron were equal to that of wüstite; the CO_2:CO ratio at which iron would be reduced would be equal to 0.31a. The activity of iron (Fe) is equal to 0.31a divided by the CO_2:CO ratio in the gas. Metallic iron will be formed only if the activity of iron is equal to unity.

It is desirable to maintain the activity of Fe in the slag appreciably below that of solid iron. This is not merely to provide a factor of safety, but because there is nearly always formed, in addition to slag, some matte or speiss, in which the Fe activity is the same as in the slag. If the Fe activity (referred to solid Fe) is only just below unity at the melting point of the slag, then solid iron will separate from the matte or speiss when it is slightly cooled, and this complicates any separation procedure outside the furnace. The Fe activity should be sufficiently below unity to ensure that iron does not separate from matte or slag at an unduly high temperature.

To summarize the basic conditions essential for good zinc blast-furnace operation, it is necessary to operate the furnace so that the gas produced contains a considerable concentration of carbon dioxide, not only because this increases the amount of heat made available per unit of carbon and, therefore, enables more zinc to be produced per unit of coke, but also in order to avoid formation of metallic iron. In order to attain good zinc elimination from the slag without reducing iron, it is necessary that the final stages of reduction are carried out at a high temperature, and this is ensured by operation with a slag of sufficiently high melting point.

Lead production

Lead oxide is reduced by carbon monoxide in the furnace shaft. The reaction

$$PbO + CO = Pb(liq) + CO_2 \qquad [4]$$

is exothermic, so that no heat is absorbed by the reduction of lead oxide to produce liquid lead. Owing to the high temperature at the top of the furnace charge, some lead is volatilized. The amount, determined primarily by the vapor pressure of lead, is about 7 pct of the weight of carbon burned. Some of this volatilized lead is condensed as liquid lead in the condenser, and the remainder forms a dross which is periodically removed and returned to the roasting plant to be re-incorporated in the sinter. Apart from a small amount contained in the slag, the balance of the lead, irrespective of the total amount charged, is collected as bullion from the furnace hearth, and contains the silver and gold present in the charge.

Since lead oxide is more readily reduced than zinc oxide, reaction [4] must occur largely near the top of the charge, so that adding lead oxide to the charge, while producing extra carbon dioxide in the final gas, has no effect on the gas composition lower down in the furnace where most of the zinc reduction occurs. The heat evolved in reaction [4] actually provides a small additional supply of heat to the furnace. The addition of lead oxide to a zinciferous charge, therefore, demands no extra carbon consumption, and makes it no more difficult to reduce the zinc oxide, so that zinc elimination is not adversely affected. The amount of lead oxide that can be reduced is, thus, limited by the concentration of carbon dioxide that can be tolerated in the gas; the ability of the lead splash condenser to handle gases containing much carbon dioxide means that this is not a very restrictive condition. If the amount of lead reduced is equal to half the weight of carbon burned, reaction [4] contributes only an extra 1 pct by volume of carbon dioxide to the gas.

In experimental work, charges containing equal weights of lead and zinc have been worked successfully, and satisfactory recoveries of both metals have been obtained. On the large furnaces, due to

shortage of materials, the highest proportion of lead which so far has been treated is equivalent to half the weight of zinc produced. As the lead content has been progressively increased (at constant carbon-burning rate), no reduction in zinc production has occurred.

At slag temperatures, the equilibrium constant in reaction [4] is about 260, so that, with a CO_2:CO ratio of about 0.5, the activity of lead oxide in equilibrium in the slag is about 0.002; this is estimated to correspond to a lead content in the slag of about 0.5 pct. In practice the lead content of the slag is found to be between 0.5 and 0.8 pct.

Copper

When only a small amount of copper is present in the charge, it is mostly reduced to metal and dissolves in the lead from which, on cooling, a copper-rich dross separates. Owing to the high activity coefficient of copper in solution in lead, the efficiency of lead as a collector for copper is less than for silver. When more than small amounts of copper are present, the copper is more efficiently collected as a matte. As already mentioned, conditions at the furnace hearth are sufficiently reducing to correspond to an effective activity of iron (referred to solid iron) that is fairly high, probably 0.5 to 0.7 pct; this means that although metallic iron as such is not produced, the matte formed is appreciably metal-rich compared with mixtures of FeS and Cu_2S. We have not yet determined the best method of operation to recover copper under those conditions. During short trials with copper-bearing charges on the big furnaces, mattes containing up to 30 pct Cu were collected but we have not yet been able to make richer mattes while still maintaining high-collection efficiency. Work is continuing on this problem.

Arsenic

In retort smelting the iron is reduced to metal; this effectively prevents volatilization of arsenic, since sufficient iron is present to form a dilute solid solution of arsenic in iron. In the blast furnace, however, iron is not reduced to metal, although the conditions are such that the activity of metallic iron is high. Under these conditions the volatilization of arsenic is restricted by the equilibrium

$$4Fe\ (a < 1.0) + As_2 = 2Fe_2As$$

Arsenic thus leaves the system as a speiss containing Fe_2As, but the equilibrium permits the volatilization of a large amount of arsenic in the hotter regions of the furnace. Most of this is recondensed as the gas leaves the charge, but a certain amount enters the condenser where it is removed with the dross made and returned to the sinter machine. A small amount enters the zinc, which can contain up to 0.04 pct As as it leaves the separation bath. Sodium is added before casting and the arsenic removed as NaAs.

Antimony and bismuth

Antimony has a somewhat lower boiling point than lead, and in absence of lead, antimony would be mostly volatilized, appearing in the condenser. In presence of lead, however, the fraction of antimony volatilized is less than the fraction of lead volatilized (since antimony is diatomic in the vapor state, its vapor pressure over its solution in lead is proportional to the square of the activity of antimony in the lead). As a consequence, almost all the antimony present in the charge appears in the bullion.

Like antimony, bismuth is mostly retained by the lead tapped from the furnace.

Condensation of zinc

In the lead splash condenser, lead abstracts heat from the gas, and dissolves the zinc which is condensed as the gas cools. This is effected by the intense shower of lead droplets thrown by the rotors revolving in the pool of lead in the condensers. The design of these rotors is such that each throws about 1000 tons of lead per hr into the gas stream.

The gas entering the condensers contains typically 5.9 pct Zn, 11.3 pct CO_2, 18.3 pct CO, the balance nitrogen. It enters the condenser at about 1000°C and leaves at 450°C. This means that the heat to be abstracted in the condenser is about 1410 cal per g of zinc condensed. The specific heat of liquid lead over the range considered is 0.033 and the lead rises by 110°C (typically 450° to 560°C), so that 1 g of lead absorbs 3.63 cal during its passage through the condenser. This means that for adequate withdrawal of temperature from the gas, the lead must be circulated at a rate equal to (1410/3.63) 390 times the rate at which zinc is being condensed.

Removal of zinc for output from the lead depends upon the reduced solubility of zinc in lead as the temperature falls. Under present optimum conditions, lead enters the condenser from the cooling and separating system at 450°C saturated with zinc, thus containing 2.15 pct Zn. It becomes heated to 560°C as it passes through the condenser and dissolves an additional 0.25 pct Zn, thus leaving the condenser with a content of 2.4 pct Zn. At 560°C the solubility of zinc in lead is 4.4 pct. As the lead passes through the cooling launders its temperature falls, and at 470°C the solubility reaches the saturation limit, and free zinc begins to form. Cooling is continued to 450°C, and the additional 0.25 pct Zn picked up in the condenser separates out. In a separating bath after the launders, the molten zinc collects above the lead and overflows into the output bath. The lead passes via an underflow weir back into the condenser to repeat the cycle.

The efficiency of the condenser is high, and only 4 pct of the zinc entering passes forward to be recovered in the wet scrubbers forming the gas cleaning system. Approximately 87 pct of the zinc vapor leaving the furnace is produced as output metal. As stated above 4 pct is produced as blue powder and 8 to 9 pct is produced as condenser cleanings and dross from the external cooling circuit. Both dross and blue powder are sent to the roasting plant where they are incorporated in the sinter and returned to the furnace, thus forming a circulating load.

Process—general observations

In the above analysis, an attempt has been made to summarize our knowledge of the physical chemistry of the many reactions which must proceed simultaneously in the furnace if all the demands are satisfied and successful commercial operation achieved. It would be presumptious to claim that this provides a complete explanation of the processes involved. The intensity and rapidity of the reactions in a blast furnace ensure that many of

Bullion, matter, speiss, and slag are tapped periodically from the bottom of the blast furnace.

them do not attain equilibrium and, therefore, the value of inference is limited. It can be claimed, however, that the analysis given above is self-consistent and is supported by the fact that the development work based upon it has been reasonably successful.

From the account given of the mechanism of zinc blast-furnace smelting, it is obvious that the conditions for successful operation must be chosen with some care. In practice, however, the process is found to be quite robust and capable of dealing with a number of variables. There are several features which can compensate automatically for variation in conditions. Thus, relatively slight changes in carbon dioxide content of the gases leaving the furnace top, which the lead splash condenser can take in its stride, will counteract quite large changes in fuel: sinter ratio. Should the furnace become overfuelled at any time and begin to produce metallic iron, an immediate correction can be applied by a drop in air preheat. This can be restored again as soon as an appropriate change in the fuel: sinter ratio has been made.

Ability to deal with a variety of materials

Due to the relatively high proportion of coke in the charge, the back pressure of the furnace remains relatively constant, and it is blown at a constant rate with a constant carbon consumption. The combustion of the carbon provides heat for the reduction of zinc oxide, the melting of the gangue and coke ash, and for the heat losses from the furnace.

The shaft furnace is less senstitive to the grade of materials fed to it than is the vertical retort or horizontal process. Thus, if the furnace is fed with sintered high-grade concentrates, a certain zinc output will be produced. On lower grade material the zinc output will be somewhat less, since, although the same quantity of carbon is burned as before, some of it is used to melt the additional gangue and less is available for reducing zinc oxide. This reduction in zinc output when treating a lower grade material can be predicted with some certainty except when excessive amounts of gangue are introduced. We have found empirically that the amount of carbon required to reduce 1 ton of zinc is 4.5 times that required to produce 1 ton of molten slag from the gangue present. From this it may be seen that the shaft process is capable of treating lower grade materials than the standard retort processes. Charges containing as little as 20 pct Zn have been treated successfully. With such materials, the zinc output of a given furnace is reduced, due to the consumption of carbon for the additional gangue to be melted, and therefore the carbon consumption per unit of zinc produced is greater than with normal concentrates. This additional cost is generally offset by a reduction in the unit price of zinc in the lower grade material.

As a result of this greater indifference to the grade of materials treated, the shaft furnace process can treat, if necessary, material higher in iron content than can the retort or electrolytic processes. To attain good zinc elimination it is necessary to produce a slag of reasonably high melting point. This can be achieved with a wide composition of the gangue material by suitable additions of lime or silica. If the iron content of the gangue is not high, it is possible to run slags in which melilite (a solid solution of gehlenite and iron akermanite) determines the melting point. A typical slag run under these conditions is 32 pct CaO, 26 pct SiO_2, 20 pct FeO, and 11 pct Al_2O_3. If the main gangue component is iron, it is possible to obtain suitable slags in which wüstite determines the melting point (e.g., 50 pct FeO, 20 pct SiO_2, 15 pct CaO, and 5 pct Al_2O_3).

The ability of the process to recover lead simultaneously with zinc has already been described and is undoubtedly one of its outstanding features. Due to the relatively stronger reducing conditions in the furnace compared with lead blast-furnace practice, the lead content of the slags lies in the range 0.5 to 0.8 pct; this enables a high recovery of lead (and consequently of silver and gold) to be achieved.

When only small amounts of copper are present, a good recovery is obtained in the bullion. When copper is present in excess of the amount required to saturate the bullion, a matte phase is formed and can be recovered, but the factors necessary to produce a high copper content matte at high recovery have not been fully determined up to the present. There seems to be no theoretical reason why this cannot be done.

Conclusion

A general description of the process[1] and operational performance[2] has been given elsewhere. Although it is young compared with the established processes, and further improvements will undoubtedly take place as experience is gained, it has already established itself as fully competitive under general conditions for the treatment of high-grade concentrates. Its special application would appear to lie, however, in the treatment of mixed concentrates from which zinc, lead, and possibly copper can be removed simultaneously, and lower grade materials with which the older processes have difficulty in dealing.

References

[1] S. W. K. Morgan: The Production of Zinc in a Blast Furnace, *Trans. of the Institution of Mining and Metallurgy*, vol. 66, Part II, 1956-57.

[2] S. W. K. Morgan and S. E. Woods: *Engineering and Mining Journal*, no. 9, September 1958.

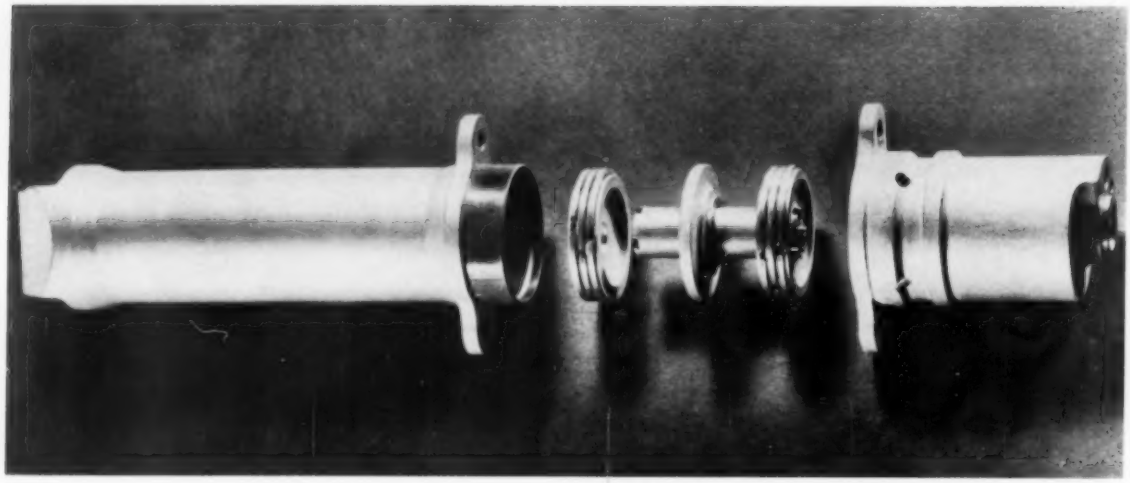


Fig. 7—M257 components in the afterburner activating cylinder assembly of Pratt & Whitney Aircraft's J75 jet engine. Courtesy of Aluminum Company of America.

DISPERSION STRENGTHENED ALLOYS: Properties and Applications of Light Metals

This month, JOURNAL OF METALS *presents the second part of a critical review of this field.*

by Claus G. Goetzel

LIGHT metals produced by powder metallurgy methods have been developed into several interesting lines of products over the past two decades. Aluminum and magnesium alloys have culminated in the dispersion-strengthened type of materials which excel in their thermal stability at temperatures above those endurable by conventional alloys. Actual and potential applications for these alloys exist in aircraft, automotive, and chemical equipment. Beryllium produced from metal powder displays a better combination of ductility and strength than that obtained by fusion metallurgy. It is of interest as contruction material for nuclear reactor components, and also has potential uses in airborne vehicles.

Aluminum

Aluminum has certain characteristics which make it the outstanding metal within the light metal group of dispersion alloys, both from a fabrication and an application point of view. The advantages include: 1) availability as fine flake and coarser atomized metal and alloy powder; 2) sufficient ductility of the metal matrix to permit the presence of substantial proportions of a second, brittle phase without rendering the product useless from an engineering viewpoint; 3) an adherent oxide film is formed, but this is practically insoluble in the metal and causes no loss of its ductility through solution strengthening; 4) the oxide phase is thermally stable at those elevated temperatures encountered in the use of aluminum alloys; 5) the metal combines with others forming intermetallic compounds which can be made to precipitate inside the powder particles and which produce similar strengthening effects to those of the oxide; 6) specific physical and mechanical properties which include low specific weight, low thermal expansion, high thermal and electrical conductivity, high corrosion and wear resistance, high temperature strength, and recovery of the mechanical properties after heating up to at least 500°C (930°F).

CLAUS G. GOETZEL is senior research scientist, New York University, New York, N. Y.

Table I. Variation of Electrical and Thermal Conductivity, Modulus of Elasticity with Oxide Content of SAP[45]

Oxide, Pct	Electrical Conductivity at 20°C, M per Ohm Sq Mm	Thermal Conductivity 20-100°C, Kcal per M Hr °C	Average Modulus of Elasticity, Psi x 10^6
0	35.0	175	8.8
5	31.0	165	9.2
10	27.8	157	9.7
15	—	—	10.2
20	20.0	140	11.0

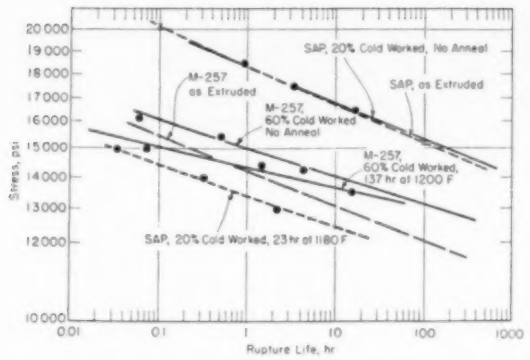

SAP, 20% Cold Worked, No Anneal
M-257 as Extruded
SAP, as Extruded
M-257, 60% Cold Worked No Anneal
M-257, 60% Cold Worked, 137 hr at 1200 F
SAP, 20% Cold Worked, 23 hr at 1180 F
Stress, psi
Rupture Life, hr

Fig. 6—Stress-rupture properties at 600°F for SAP and M257.[19]

The properties of Sintered Aluminum Powder (SAP) have recently been summarized and compared with the alloy's American counterpart by several investigators, notably Irmann,[40, 43] Lenel and co-workers,[8] and Grant and co-workers.[19] Lenel's comparison between the tensile strength of commercial and experimental powder extrusions as a function of the oxide content was reproduced in Fig. 5 (JOURNAL OF METALS, March 1959). For SAP alloy containing 14 pct oxide, the room temperature UTS exceeds 50,000 psi, and the Brinell hardness 100.[43] A sign of the excellent retention of properties after long periods of high-temperature soaking is the fact that after 1 year at 500°C (930°F), SAP still has a room temperature UTS of 44,000 psi. When tested at 500°C after soaking for 1 month at the same temperature, the UTS is over 13,500 psi, i.e., more than six times that of heat-treated Y-alloy (142) tested under identical conditions. Stress-rupture properties of extruded SAP bar stock and 20 pct cold-worked metal at 600°F (315°C) were found to be identical, and considerably superior to M257 after extrusion and after 60 pct cold reduction, as shown in Fig. 6.[19] The large decrease in strength after an anneal at 638°C (1180°F), even below that of M257 annealed at 650°C (1200°F), was caused by blistering due to gas evolution near the solidus temperature. Creep strength of SAP containing approximately 13 pct oxide for 0.2 pct permanent deformation and a test period of 1 month is 9600 psi for 400°C (750°F), the fatigue strength at 100 x 10^6 cycles for the same temperature is 8000 psi, and for room temperature 15,000 psi.[43] Table I summarizes the electrical and thermal conductivities and Young's modulus for SAP alloys of different oxide content.

Effect of alloying elements

Irmann[40, 43] has also reported on attempts to improve the elevated temperature properties of SAP by adding alloying elements, such as copper and magnesium. Surprisingly, the rate of diffusion of copper in aluminum was found to be appreciably quicker in SAP than in pure aluminum, and broader diffusion zones of copper were found. Irmann concludes that in addition to the normal slow diffusion through the grains, a high rate of diffusion takes place through the grain boundaries as well as through the oxide layers on the individual particles. After heating to 100°C (212°F) an Al-Cu-Mg-Mn-type SAP alloy (Avional 17S) displayed a 50 pct higher tensile strength at room temperature than unalloyed SAP, due to an age-hardening effect being superimposed on the dispersion strengthening process. This additive effect of aging is gradually diminished with increasing soaking temperature, until the strength level of unalloyed SAP is reached after heating to 400°C (750°F). On testing at the soaking temperature, the UTS of the alloy-SAP is again about 50 pct higher than that of pure Al-SAP for 100°C (212°F), but the two coincide at 200°C (390°F) and the alloy-SAP falls below that of the Al-SAP at higher temperatures. At 500°C (930°F), the UTS is only about half that of the pure Al-SAP. The reason for this behavior is not clear, and cannot be fully explained by the peculiar aging characteristics of the alloy-SAP discussed by Irmann.[43] His conclusions that the oxide content of the pure powder, as a function of particle size and surface film, plays a dominant role in tensile strength at ordinary and elevated temperature, seems to be supported by these experiments. Noteworthy is the fact that the alloyed SAP products were found to display a smaller thermal expansion and better wear resistance, which may be of interest for certain applications such as jet engine compressor bladings and the like.

The properties of Alcoa's Aluminum Powder Metallurgy (APM) products, M257 and M276, have recently been compared with a series of wrought alloys by Lyle.[44]

Tables II, III, and IV compare the tensile properties at room and elevated temperatures, and the stress-rupture and creep properties at 400° and 600°F (205° and 315°C) of M257 and M276 with M430 and M470, the latest APM alloys.[45] It is significant that the elongation of the APM products in the elevated temperature tests tends to decrease with temperature in contrast to conventional alloys. The higher elongation values for M257 result in an improved workability. All alloys of this category tend to take on a preferred orientation of the crystallites during mechanical working. The degree of preferred orientation decreases as the number of finely dispersed particles increases and the distance between them decreases, indicating how effectively the dispersed phase interferes with slip in these alloys.

The atomizing process permits the production of fine uniform dispersions of certain alloying elements

Table II. Tensile Properties of APM Extrusions[45]

Test Temperature*	Tensile Strength, Psi				Yield Strength, Psi**				Elongation, Pct***			
	M257	M276	M430	M470	M257	M276	M430	M470	M257	M276	M430	M470
21°C (70°F)	37,000	51,000	52,000	43,000	24,000	34,000	35,000	29,000	17	7	7	10
315°C (600°F)	17,000	22,000	23,000	20,000	15,000	20,000	22,000	18,000	13	6	7	8
427°C (800°F)	12,000	16,000	17,000	15,000	11,000	15,000	17,000	14,000	5	3	3	4
538°C (1000°F)	7,500	10,000	10,000	8,700	7,000	9,000	10,000	8,500	2	2	3	2

* After ½ hr at temperature.
** 0.2 pct offset.
*** In 4 diameters.

Table III. Stress-Rupture Properties of APM Extrusions at 205°C and 315°C (400° and 600°F)[45]

Test	Stress for Rupture, Psi			
	M257	M276	M430	M470
400°F, 100 hr	17,000	23,000	23,000	21,000
400°F, 1000 hr	16,000	21,000	21,000	20,000
600°F, 100 hr	11,500	14,000	15,500	14,000
600°F, 1000 hr	10,500	12,500	14,000	—

Table IV. Creep Properties of APM Extrusions at 205°C and 315°C (400° and 600°F)[45]

Total Creep		Temperature, °F	Stress, Psi			
Pct	Hr		M257	M276	M430	M470
1	100	400	16,000	22,000	23,000	21,000
1	100	600	11,000	—	—	14,000
0.5	10	400	16,500	23,000	23,000	21,000
	100		15,000	21,000	21,000	19,000
	1000		—	19,000	19,000	17,000
0.5	10	600	12,000	14,500	15,500	14,000
	100		10,000	13,000	14,500	13,000
	1000		—	11,500	13,000	—
0.2	10	400	14,000	20,000	21,000	20,000
0.2	10	600	10,500	12,000	12,500	12,000

in the form of insoluble compounds such as $FeAl_3$ or $CrAl_7$, and small dendrite size within the individual, relatively coarse-grained powder particles. These hard compound constituents do not go into solution or increase in size at elevated temperatures, so that the initial dispersion is retained throughout fabrication into the finished product.

Extrusions of some atomized aluminum alloy powders containing fairly large amounts of such elements as iron and chromium have displayed tensile, stress-rupture, creep, and fatigue properties that generally compare favorably with those of the Al_2O_3-type alloys. Table V summarizes the mechanical and physical properties of three of these new alloys and compares them with M257.[7] The complex alloy M486, containing 7.8 pct iron and 0.2 pct each of chromium, titanium, vanadium, and zirconium, appears to have outstanding properties in the range between 205° and 427°C (400° to 800°F). According to Towner, the atomized powders for a given tensile strength level at 315°C (600°F) have better fatigue properties but slightly poorer creep characteristics than the Al-Al_2O_3 alloy M276. Even more significant is the fact that the ductility of the atomized powder alloys increases with temperature analogous to conventional alloys, but in contrast to the oxide-base dispersion SAP and APM alloys made from unalloyed flake powder. This characteristic gives the atomized powder an appreciable edge with regard to hot-working operations as well as performance in actual service. An added advantage of the atomized powder products is a high modulus of elasticity without excessively increased density, thanks to the addition of substantial amounts of the moderately heavy elements iron and chromium.

Applications of SAP and APM

SAP and APM products are fabricated in various forms customary for wrought alloys. These include bars and rod, profiles, tubes sections, forgings, stampings, sheet and strip. Joining of SAP and APM, sheet and plate poses problems but may be accomplished satisfactorily either by pressure welding or by mechanical means. Fusion welding methods involving filler metal lead to porosity and agglomerations of the dispersed phase. Surface protection of SAP and APM products is accomplished by electroplating (e.g., hard chromium, silver) and by anodizing (e.g., Alumilite hard coating).

Many applications, potential and actual, have been listed by Irmann,[46, 48] Lyle,[44] and others. Irmann cites pistons, piston rods, piston inserts, cylinder heads, small wheels, and jet engine compressor bladings for the automotive and aircraft industries and even suggests skins for supersonic aircraft. Applications in the electrical apparatus, instrument, and chemical industries include small turbine casings, hot-air fan wheels, heat exchangers, and wear-resistant parts. An important potential application in atomic energy is a fuel element cladding permeable to neutrons. Lyle cites the successful production of extruded rod up to 6 in. in diam for spacers, heat seal rings, and forging stock. Hot-air valve housings and flanged pneumatic cylinders were machined from extruded profile shapes. Examples of APM die forgings include compressor discs, fan blades, and a variety of fittings, fasteners, caps, and miscellaneous small parts. Rivets, bolts, and screws have been made from M257 wire. M257 sheet has been produced into various kinds of heat shields and honeycomb sandwiches. Fig. 7 shows M257 parts for use in the afterburner activating cylinder assembly in Pratt & Whitney's J75 jet engine.[48] M257 was chosen over other aluminum alloys, titanium, and stainless steel, because of favorable weight, machinability, thermal conductivity, finishing, and stability of properties and dimensions, as well as cost. Of particular importance was the ability to apply a hard abrasion-resistant anodizing coating.[48]

Widespread application of SAP and APM products in industry have apparently been handicapped by two problems, cost and low ductility. The production of these alloys from flake powder is considerably more expensive than that of aluminum alloys by normal melting methods followed by rolling, forging, or extrusion. The established fact that optimum thermal stability and high-temperature strength require very fine flake powders imposes a cumbersome process of milling, and serious problems of handling and consolidating large quantities of reactive powder of great volume and surface area. The new family of atomized alloys shows considerable promise of overcoming these handicaps, thus opening a wide field of uses where costs and quantity are as important as properties. Since no milling is necessary, and the alloys are produced in the molten state and solidified as coarse-granular powders, large-scale production at a cost comparable to that of standard wrought aluminum alloys appears feasible. Better combinations of ductility and strength of the atomized alloys are an additional incentive.

Magnesium

Compared with aluminum, efforts to produce and industrially apply dispersion-strengthened magnesium alloys have been very limited. Mg-MgO alloys, analogous to the Al-Al_2O_3 alloys, have shown increased room and elevated temperature strength over the pure metal, in spite of the use of rather coarse flake magnesium powder.[1] However, under the sponsorship of Dow Chemical Co.[30] the development of extruded powder products has primarily been concerned with coarse-granular magnesium-

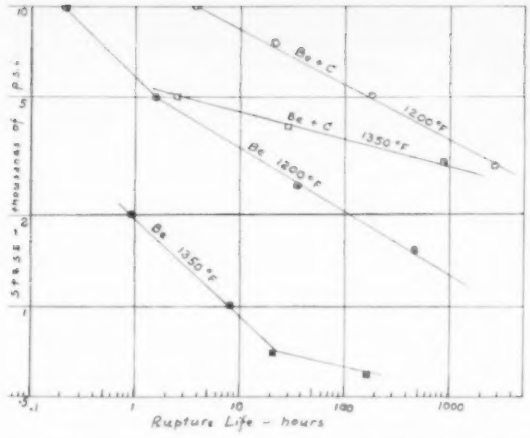


Fig. 8—Log stress vs log rupture life for beryllium and beryllium-carbon powder extrusions at 1200° and 1350°F (650° and 730°C).[1] The Be-C products contained equivalent of 2.5 pct Be_2C.

alloy powders obtained by atomization, i.e., dropping a stream of molten alloy upon a horizontally rotating wheel. The technique of consolidating these coarse powders, whose particles or pellets average 350μ, is essentially the same as that used for cast products. The principle advantage of the powder extrusions lies in their fine grain size, which finds its origin in the finely cored dendritic structure of the particles caused by the rapid chill during atomizing. This fine grain size is important in magnesium alloys, as it improves the ratio between the compressive and tensile yield strength. Coarse-grained alloys tend to have a compressive yield strength considerably below their tensile yield strength because of the deformation behavior of magnesium crystals (slip under tensile loads and twinning under compressive loads).

Busk and Leontis[10] have outlined potential advantages of Mg-alloy extrusions from powder, notably the co-extrusions of mixtures of two powders of different alloy composition, incompatible in a cast alloy, e.g., Mg-Al and Mg-Zr. These mixtures form a type of dispersion-strengthened alloy through diffusion and the formation of a precipitate of an insoluble intermetallic compound. The alloy ZK60 (6 pct Zn, 0.7 pct Zr) plus 0.5 pct Ca has excellent mechanical properties, but its extrusion speed is limited to 1 fpm. If this alloy is diluted by adding 50 pct of alloy M1 (1.2 pct Mn), the extrusion rate can be considerably raised, but the properties are much lower. If, however, 12 pct of Mg-Al eutectic is added to the 50-50 alloy combination, a dispersion or interference-hardening reaction takes place with the result that the mechanical properties of the original alloy ZK60 plus 0.5 Ca are nearly restored while the permissible extrusion speed is increased five-fold.

Magnesium pellet extrusions have been reported[16] in use in certain structural arrangements inside the fuselage of aircraft such as the C133 cargo plane.

Beryllium

In view of the great difficulties encountered in the production of beryllium of sufficient ductility for most engineering applications, little effort has been made to introduce intentionally a high-temperature stabilizing second phase. One investigation reported

Table V. Mechanical and Physical Properties of Extruded APM Alloys at 21°, 315°, and 427°C[7]

	Atomized Alloys			Flake Alloys
	Experimental—7.6 Pct Fe	Experimental—5.5 Pct Fe, 5.0 Pct Cr	M186—7.8 Pct Fe, 0.2 Pct each Cr, V, Ti, Zr	M257—8 Pct Al_2O_3
Tensile properties at 70°F				
Tensile strength, psi	45,000	56,800	48,300	37,000
Yield strength, psi	31,400	44,300	34,100	24,000
Elongation[a], pct	16	1.0	15	17
Tensile Properties at 600°F[b]				
Tensile strength, psi	21,900	27,100	24,300	17,000
Yield strength, psi	17,800	20,300	20,800	15,000
Elongation[a], pct	19	4	16	13
Tensile Properties at 800°F[b]				
Tensile strength, psi	10,000	12,000	14,000	12,000
Yield strength, psi	7,800	7,400	10,800	11,000
Elongation[a], pct	28	9	23	5
Stress to Rupture at 600°F				
for 100 hr, psi	12,000	11,000	16,000	11,500
for 1000 hr, psi	10,000	9,000	13,000	10,000
Creep Stress at 600°F				
for 1 pct in 100 hr, psi	10,000	9,000	13,000	11,000
for 0.5 pct in 10 hr, psi	10,000	9,500	14,000	12,000
for 0.2 pct in 1 hr, psi	9,000	9,000	13,000	11,000
Modulus of Elasticity, Psi				
at 70°F	11.4×10^6	12.5×10^6	11.7×10^6	10.6×10^6
at 600°F	8.2×10^6	9.0×10^6	8.8×10^6	7.6×10^6
at 800°F	5.7×10^6	6.2×10^6	6.4×10^6	6.6×10^6
Density	2.88	2.91	2.89	2.74
Electrical Conductivity[c]	42	25	26	51
Thermal Conductivity[d]	0.39	0.25	0.26	0.46

[a] In 4 diameters.
[b] After 100 hr at temperature.
[c] Pct of standard, at 25°C.
[d] Cgs units, at 25°C.

by Grant and Preston[1] concerned the system Be-C. Since Be_2C is essentially insoluble in solid beryllium, a fine and uniform dispersion could be obtained in mechanical mixtures of the metal powder and carbon which were compacted, sintered, and extruded. Stress-rupture tests at 650° and 733°C (1200° and 1350°F) showed that the creep-rupture strength of 0.8 pct C (2.5 pct Be_2C) powder extrusions was considerably greater at the higher temperature than that of pure beryllium at the lower temperature, and that the slope of the log stress-log rupture time curve was considerably flatter, which is typical for effective dispersion strengthening, Fig. 8.

In general, beryllium powder metallurgy products are not intentionally produced in form of dispersion-strengthening alloys. However, they may be considered as belonging to this category of material by virtue of the role played by the BeO. Mechanical properties are mainly controlled by grain size, which in turn is determined by the particle size of the powder, the amount and distribution of the BeO, and the degree of consolidation.[17, 18] In general, optimum room-temperature properties are achieved with fine grain size, maximum consolidation and minimum oxide, and other impurities, particularly of the type forming compounds with beryllium. At elevated temperatures, e.g., 500°C (930°F), a coarser grain size as well as an increased proportion of refractory compounds (BeO) appears to increase the strength, but this adversely affects the fabrication by mechanical working which requires relatively weak metal with maximum ductility in all directions. The nuclear properties and corrosion resistance of beryllium are greatly affected by the method of producing the powder and the subsequent operations.The preferred method of production involves vacuum melting of metal produced by magnesium-reduction of beryllium fluoride, followed by machining into chips and mechanical attritioning to

Table VI. Some Room Temperature Tensile Properties of Beryllium Processed By Powder Metallurgy and Vacuum Casting Without Further Mechanical Working[50]

	Ultimate Tensile Strength, Psi	Tensile Elongation, Pct
Vacuum cast	20,000	0.1
QMV —200 Mesh Powder		
Cold pressed and vacuum sintered		
1050°C (1922°F)	32,000	0.1
Warm pressed without sintering		
450°C (840°F) at 200,000 psi	30,000	0.2
565°C (1050°F) at 140,000 psi	46,000	0.1
650°C (1200°F) at 100,000 psi	58,000	0.1
Warm pressed 450°C, (840°F) at 200,000 psi vacuum sintered at 1050°C (1920°F)	36,000	0.2
Hot pressed in Atmosphere		
750°C (1380°F) at 30,000 psi	52,000	0.0
1100°C (2010°F) at 3000 psi	68,000	1.4

—200 mesh powder. Other methods, such as reduction or milling to flake, apparently give inferior products because of increased amounts of impurities, usually slag, adhering to the particle surfaces.[50]

The BeO content of the powder is a function of the particle (mesh) size and the number of passes through the Be-faced attrition mill. It ranges from 0.2-0.5 pct for the coarse fractions to 1.0-1.8 pct for the —400 mesh fraction.

Processing of beryllium through powder metallurgy is at present the most important fabrication method for the production of structural components. Vacuum hot pressing, preferred in the US, and cold pressing and vacuum sintering, can result in highly densified bodies that can be fabricated into finned and fluted tubes, splined cylinders, cups, etc.[50] Rods, single profile shapes, and a variety of tubes may be fabricated by extruding hot-pressed or cold-compacted powder billets either warm or hot, i.e., below or above the recrystallization temperature. For this purpose, the billets are sheathed. The usefulness of the extrusion technique is somewhat limited by the inability of the extruded product to be further sized by cold-working operations.

Properties of beryllium powder

The properties of beryllium powder metallurgy products and their dependence upon the details of the processing and fabrication operations have been extensively discussed by Beaver,[49, 50] Loewenstein, Kaufmann and Arnold,[51] and also by Hausner and Pinto.[52] In Table VI some room-temperature tensile properties of cold-pressed and sintered, warm-pressed, and hot-pressed beryllium powder compacts are compared with vacuum-cast metal. The mechanical properties of several grades of hot-pressed beryllium, including the commercial grade *QMV* of the Brush Beryllium Co., are summarized in Table VII. In special experiments the object of which was the determination of the effect of oxygen (without slag) on the processing of beryllium powder, it was found that different methods and BeO contents had little effect on the tensile properties of warm and hot-pressed powder. But lower strength values and lower ductility were found in warm-extruded powders containing very high percentages of BeO (3.6 pct) than in standard products containing only 0.82 pct. The latter had a UTS and YS of 76,600 and 44,100 psi, respectively, and an elongation of 6.6 pct.[50] Room-temperature tensile elongations up to 20 pct along the extrusion axis have been reported to be attainable under proper conditions of powder preparation, compaction, and extrusion.[51] The well-known absence of elongation in the direction perpendicular to the worked surface planes (which must be chiefly attributed to the unfavorable *c/a* ratio of the hexagonal unit cell) has been the main obstacle to greater ease of fabrication of large sheet and profile shapes. This, too, has so far greatly limited the safe use of beryllium powder products for airborne vehicles.

Table VII. Some Room Temperature Mechanical Properties of Vacuum Hot Pressed Beryllium Powder[50]

	QPT	QRM	QMV
Ultimate tensile strength, psi	38,500	36,400	45,200
Tensile yield (0.2 pct), psi	32,900	35,600	32,100
Tensile elongation, pct	1.9	1.1	2.3
Tensile modulus of elasticity, psi at 20°C (68°F)	—	44.7×10^6	44.4×10^6
Temp. coef. of modulus, psi per °C	—	—8500	—7700
Compression yield (0.2 pct), psi	26,000	28,900	24,600
Compression modulus, psi	44.3×10^6	44.3×10^6	44.2×10^6
Poisson's ratio	0.025	0.028	0.024
Shear ultimate (torsion), psi	—	31,300	38,900
Shear ultimate (double shear), psi	40,600	40,400	36,800
Shear yield (0.2 pct) (torsion), psi	—	16,600	18,300
Shear modulus (torsion), psi	—	19.0×10^6	21.5×10^6
Unnotched charpy impact, ft-lb	—	—	0.8
Tensile impact, ft-lb	—	—	1.4

Summary

The future increase of the applications of dispersion-strengthened light metals seems to depend largely on the development of industrially feasible methods of producing pulverulent starting materials of particle sizes that can be handled and controlled. Methods of production and consolidation of these powders must be manageable with conventional plant facilities permitting high production rates at reasonable cost. At present, the atomizing and mechanical disintegration processes resulting in the coarser particle type appear to be the best way to accomplish these objectives. The encouraging combination of excellent ductility, strength and creep resistance displayed by some of the atomized aluminum alloy powder products seems to offer a stimulus for a wider field of application as well as for further alloy development reaching into the realm of higher melting metal systems.

References cited

[1] N. J. Grant and O. Preston: Dispersed Hard Particle Strengthening of Metals. *AIME Trans.*, 1957, vol. 209, pp. 349-360; JOURNAL OF METALS, March 1957.

[2] F. V. Lenel, A. B. Backensto, Jr., and M. V. Rose: Properties of Aluminum Powders and of Extrusions Produced from Them. *AIME Trans.*, 1957, vol. 209, pp. 124-130; JOURNAL OF METALS, January 1957.

[7] R. J. Towner: Atomized Powder Alloys of Aluminum. *Metal Progress*, May 1958, vol. 73, No. 5, pp. 70-76, 176, 178.

[10] R. S. Busk and T. E. Leontis: Powdered Magnesium Alloys, *AIME Trans.*, 1950, vol. 188, pp. 297-306; JOURNAL OF METALS, February 1950.

[39] W. S. Cremens, E. A. Bryan, and N. J. Grant: Temperature and Time Stability of M257 and SAP Aluminum-Aluminum Oxide Alloys. ASTM 1958 Preprint No. 84.

[40] R. Irmann: S.A.P.-der Aluminium-Sinterwerkstoff mit hoher Warmfestigkeit. *Aluminium*, 1957, vol. 33, No. 4, pp. 250-259.

[42] R. Irmann: Sintered Aluminum Powder. *Symposium on Powder Metallurgy*, 1954, Special Report No. 58, The Iron and Steel Institute, London, 1956, pp. 236-241.

[44] J. P. Lyle, Jr.: Aluminum Powder Metallurgy Products. *Proceedings Twelfth Annual Meeting*, Metal Powder Association, Cleveland, 1956, pp. 93-107.

[45] J. P. Lyle, Jr., Private communication.

[46] Alcoa Crashes the Heat Barrier. *Aviation Week*, February 17, 1958, p. 90.

[47] F. V. Lenel: Powder Metallurgy—Now. H. W. Gillett Memorial Lecture ASTM, 1955, p. 21.

[48] R. S. Busk: Private communication.

[49] W. W. Beaver and K. G. Wikle: Mechanical Properties of Beryllium Fabricated by Powder Metallurgy. *AIME Trans.*, 1954, vol. 200, pp. 559-573.

[50] W. W. Beaver: Fabrication of Beryllium by Powder Metallurgy. *The Metal Beryllium*. ASM Cleveland, 1955, pp. 152-201. Also *Metal Progress*, April 1954, vol. 65, No. 4, pp. 92-97.

[51] P. Loewenstein, A. R. Kaufmann and S. V. Arnold: Mechanical Working of Beryllium by Extrusion. *The Metal Beryllium*. ASM Cleveland, 1955, pp. 241-261.

[52] H. H. Hausner and N. P. Pinto: Research and Development in Beryllium Powder Metallurgy. *The Metal Beryllium*. ASM Cleveland, 1955, pp. 202-240.

Enhanced Diffusion

JOURNAL OF METALS presents the report on the Conference on Enhanced Diffusion, held at the University of Pennsylvania on Oct. 1, 1958.

by G. J. Dienes

SEVERAL groups of investigators have been working during the last 2 to 3 years on the influence of the non-thermal generation of crystalline defects (vacancies, interstitials) on diffusion processes in metals. Two methods of non-thermal generation of defects have been used in these experiments: nuclear irradiation and steady plastic deformation (creep).

The Brookhaven results on irradiation with fast particles showed the formation of vacancies and interstitials by means of knocking atoms out of their normal positions in the crystal. The elementary process of defect generation is truly non-thermal in this case. At any but the lowest temperatures, the defects will be mobile and tend to disappear from the crystal by migrating to dislocations, grain boundaries, and by mutual annihilation of vacancies and interstitials. The two opposing rate processes, generation of defects and their annealing, will create, in dynamic equilibrium during irradiation, an excess steady state concentration of defects.

Since atomic diffusion in metals occurs via defects (mainly vacancies), enhanced-diffusion rates are to be expected. The steady state concentration of defects introduced this way is small and the enhancement is important only at temperatures below the self-diffusion range where the thermal concentration of defects is extremely small. A simple theory, based on a constant, temperature-independent, production rate by irradiation, and on a temperature-dependent rate of anneal proportional to defect concentration, has been worked out. The simple theory predicts that the enhanced-diffusion rate should be temperature independent over a rather wide temperature range. Experiments at Brookhaven on alpha brass confirmed the above features of radiation-enhanced diffusion.

Role of plastic deformation

Crystalline defects can also be produced by plastic deformation, as a matter of fact, at a much higher rate than in most nuclear reactors. Consequently, the enhancement in diffusion rates is directly observable by straightforward, radio-active tracer techniques as a change in the self-diffusion coefficient of a metal. A steady state condition, similar to that in the irradiation case, may be set up by maintaining the sample in steady state creep during the self-diffusion experiment. Qualitatively, many of the features discussed for the irradiation experiment are expected to be valid for diffusion enhanced by plastic deformation. The situation is more complicated, however, because the mode of defect production is far more complex and is probably temperature dependent. Further, an excess steady state concentration of dislocations, as well as simple defects, may be produced by plastic deformation. These extra dislocations may lead to enhanced diffusion by means of fast diffusion along them (dislocation short circuiting). Full interpretation of the plastic deformation experiments is not yet at hand, but the following salient features of the process have been well verified:

1) The enhancement in the self-diffusion coefficient at any given temperature is proportional to the strain rate. This has been verified for iron in compression (MIT), for silver in torsion (Pennsylvania), and in compression (NACA) over a wide range of strain rates and at various temperatures. The enhancement can be very large indeed; for example, the MIT group has observed an enhancement in self-diffusion in iron by a factor of 1000 at 757°C and at a steady creep rate of 2×10^{-8} sec^{-1}.

2) The enhancement is larger at the lower diffusion temperatures and, of course, at the higher strain rates. If the results are expressed in terms of an effective activation energy, the activation energy is found to decrease drastically as the strain rate is increased. The NACA experiments indicate that a temperature-independent, enhanced-diffusion constant is being approached at the lowest temperatures (538°C for silver); this is analogous to the irradiation case. A truly temperature-independent range has not yet been observed experimentally during plastic deformation. At higher temperatures the temperature dependence becomes rather complicated, presumably because the production process itself is temperature dependent.

3) There is gratifying agreement between the Pennsylvania and NACA experiments on silver strained in two different ways, torsion and compression, respectively. These experiments were done in the 550° to 800°C range. The Illinois group (J. B. Darby, C. T. Tomizuka, and B. W. Balluffi) does not find any enhancement in silver clearly outside of experimental error in tension or compression at 900°C. This discrepancy is probably apparent rather than real since extrapolation from the lower temperatures indicates that the enhancement is very small at 900°C. However, there seem to be serious discrepancies in some of the experimental results from the various groups at 800°C. Further careful experiments are clearly needed.

Conclusions

Although some discrepancies still exist, the salient experimental features for enhancing diffusion have been established.

One feature which is rather obscure at this point is the role of defects other than vacancies. One cannot differentiate between these defects on the basis of the irradiation experiments that have been done to date. There is some hope that conditions can be modified to yield the required pertinent information. In the case of the plastic deformation experiments, a full quantitative interpretation of the data is required before the role of the two primary point defects is clarified.

G. J. DIENES is with Brookhaven National Laboratory, Upton, N. Y. Support of the Conference by the AEC, particularly through the interest of D. K. Stephens, is acknowledged by Prof. Maddin, chairman of the Metallurgy Dept. at University of Pennsylvania.

Jim Ryan, assistant convention manager, at his last Annual Meeting before retirement.

THE 1959 ANNUAL MEETING

Cable cars, exotic dinners, jazz clubs, Fishermen's Wharf, Chinatown, and yes (!) technical sessions and committee meetings too.

A Staff-written Summary

In stark contrast to the blizzard which greeted AIME members last year were the balmy breezes of San Francisco at the 1959 Annual Meeting. The spring-like weather with showers—called heavy storms with sweeping gales in the local press—made it difficult for many of us from the colder realms to realize that it was still February and not yet April or May. Cries were heard from many quarters that the Annual Meeting should be brought to San Francisco more often than every ten years.

The Annual Meeting—described by some as probably the largest in the history of AIME, and by others as possibly one of the largest conventions ever held in San Francisco—got underway on Sunday, the 15th of February, at the Sheraton-Palace, Sir Francis Drake, and St. Francis Hotels, The Metallurgical Society making its headquarters at the latter with 840 registered members present.

Education was the chief attraction for the Sunday meetings, and *Current Issues in Metallurgical Education* was the title of the session sponsored by the Committee on the Metallurgical Profession and the Education Committee of The Metallurgical Society. T. B. King went into detail on the future of process metallurgy and what this means to the efforts of educators in this field. The controversy over materials engineering became the topic of discussion which followed the talk by R. F. Mehl entitled *Orthodoxy, Heterdoxy, and Metallurgical Education.* R. A. Flinn followed with a paper in which he showed how the University of Michigan's recently initiated course of study in materials engineering appears to be working out in practice. Although it is somewhat early to draw any conclusions, Dr. Flinn did point out how the course was integrated with the more traditional metallurgical courses at Michigan. (JOURNAL OF METALS hopes to re-enter this controversy—see JOURNAL OF METALS, Dec., 1958, p. 796—shortly with a summary of the papers by Drs. Mehl and Flinn.)

This most interesting afternoon session was followed by the Council of Education Buffet Dinner, at which time Lysle E. Shaffer, of the University of California, formally took over as President of the Council. O. C. Shepard, outgoing President of the Council, presented the *Mineral Industry Education Award* to Allison Butts, professor emeritus of metallurgy at Lehigh University. The award was presented "For his notable role as a teacher and administrator, his many contributions to basic knowledge in metallurgy, his pioneer work in mineral economics, his assistance to his government, and his inspiration to his colleagues and those who have followed him."

Dr. Teller speaks

The major event of Sunday evening was the Council of Education Technical Session at which Edward Teller, of the University of California, described *Peaceful Uses of Nuclear Explosives.* Dr. Teller said that the time for the economic utilization of nuclear explosives for peaceful purposes is at hand. Nuclear explosives open up a completely new field which might be called geographical engineering. It pertains only in part to the most obvious utilization of atomic explosives—major earth-moving operations, such as might be used for harbors

"The Society is pleased to award to . . ."

C. T. Marshall, the J. E. Johnson, Jr. Award (presented by Karl Fetters).

L. W. Boyd, Jr., a $100 check for winning the Student Prize Paper Contest (presented by Prof. John Butler).

B. W. Gonser, a plaque for his service as EMD Chairman (presented by H. H. Kellogg).

J. J. Gilman, the Mathewson Gold Medal and the Rossiter W. Raymond Memorial Award (presented by W. J. Harris, Jr.).

and canals. The so-called *clean nuclear explosives* could be used for these jobs, making it possible to cut the radiation effect from explosions to 1/20th of their previous levels.

As far as harbors are concerned, explosions could take place in such a manner that the radioactive products would mix with ocean water, thereby being distributed through the vast seas and to the ocean depths, rendering these materials largely harmless. Furthermore, the explosives could be buried in such a manner as to eliminate harmful radiation effects beyond a distance of some 15 miles. Man could probably return to such areas in a matter of a few weeks. There are numerous examples of sparsely populated localities where harbors could be thus constructed to provide facilities for tapping a region's resources.

Another possible use of nuclear explosives might be for the relatively cheap stripping of overburden rock which covers mineral deposits. Such a stripping might be easily accomplished to a depth of some 200 ft. Nuclear explosives could also be used in breaking up rock underground to make possible the flow of oil so that it could be more easily tapped. Water-impermeable rock formations could also be so broken up as to be transformed into water-permeable formations, permitting the transfer of water to previously arid regions. Atomic Energy Commission experience with underground explosions has shown that the radioactive products of explosions are generally contained in silica-like insoluble nodules resulting from the vaporization of silica-containing rock in the vicinity of the explosions. Whether this will always be the case Dr. Teller could not say; furthermore, much rock contains no silica. Thus the results in these cases is unknown.

Still another use of nuclear explosives was described by Dr. Teller. This was the transformation of tar sands, and even shales, into such a form that the oil would be liquid. There are vast deposits of oil which, when heated to 60°F, would be permanently transformed to a fluid substance. Nuclear explosions could provide the necessary heat and break up these formations so that hot water could be pumped through them.

Oil shales present a more difficult problem, since they must be heated to several hundred degrees to cause them to give up their oil, but by breaking up the formations through a nuclear explosion underground, retort action might be initiated. This might provide sufficient heat for liquification. Such oil shales greatly exceed the total oil reserves of the world, and may become an important source material thanks to the use of nuclear explosives. Dr. Teller concluded his remarks by saying that the peaceful uses of nuclear explosives may actually surpass those of nuclear energy.

And Monday

Monday featured sessions on interfaces and surfaces, iron ore reduction, electrolytic extractive processes, lead, dislocations, beryllium, iron blast-furnace engineering, plutonium, and copper. From these sessions and others of the Meeting, JOURNAL OF METALS will publish several of the most important papers during the next few months.

A feature of the Monday program was the Wel-

Lectures by distinguished scientists, including . . .

Edward Teller, shown after his talk to the AIME Council of Education.

Clarence E. Sims, shown delivering the annual Howe Memorial Lecture.

Frederick Seitz, this year's IMD Lecturer.

W. J. Kroll, who delivered the first EMD Lecture.

coming Luncheon held in the Garden Court of the Sheraton-Palace Hotel. The program was under the chairmanship of AIME President Augustus B. Kinzel, who first introduced and thanked E. M. Barker, Chairman of the San Francisco local section, which played host to the convention.

Canadian Insitute of Mining and Metallurgy President David G. Burchell was presented; he extended greetings and best wishes from his society and commented on the long and good relations between the two societies.

At the Welcoming Luncheon prizes were awarded in the Institute's Seventeenth National Student Prize Contest. Supervised by a subcommittee under the chairmanship of John Butler, the awards are $100 cash prizes for papers in two classifications: graduate and undergraduate. In The Metallurgical Society, Leonard W. Boyd, Jr. received the undergraduate award for his paper entitled *Ferromagnetism in Some Alloys of the Copper-Manganese-Tin System*, entered by the Montana section. The graduate award went to Charles H. Pitt for a paper entitled *Carbon Dioxide Adsorption on Thoria*, entered by the Utah section.

The luncheon speaker was introduced by Donald H. McLaughlin, president of the Homestake Mining Co., a regent of the University of California, and a Past President of the AIME. "Element discoverer—plutonium, berkelium, and others" — "recently elected chancellor of the University of California" were the words used to introduce Glenn T. Seaborg. He spoke on the other facet of peacetime uses of the atom, namely nuclear power and its future. Mentioning fission and fusion, Dr. Seaborg said he felt that although the former is in the course of development, it would take at least 20 years to solve the problems of producing nuclear energy through fusion. On a world-wide basis, the early development of energy through fission has been emphasized in western Europe and Japan, areas lacking in adequate energy supplies. This group is using the quick approach to energy from fission, namely, the utilization of natural uranium without separating the isotopes. A second group of countries, the US, West Germany, and the USSR, are using a slower and, in the opinion of the speaker, a sounder approach to energy by fission. This consists of first separating the isotopes of uranium and then using them in a smaller sizereactor. In this regard, the US and the USSR are parallel in their approach to nuclear power.

And then there was Tuesday

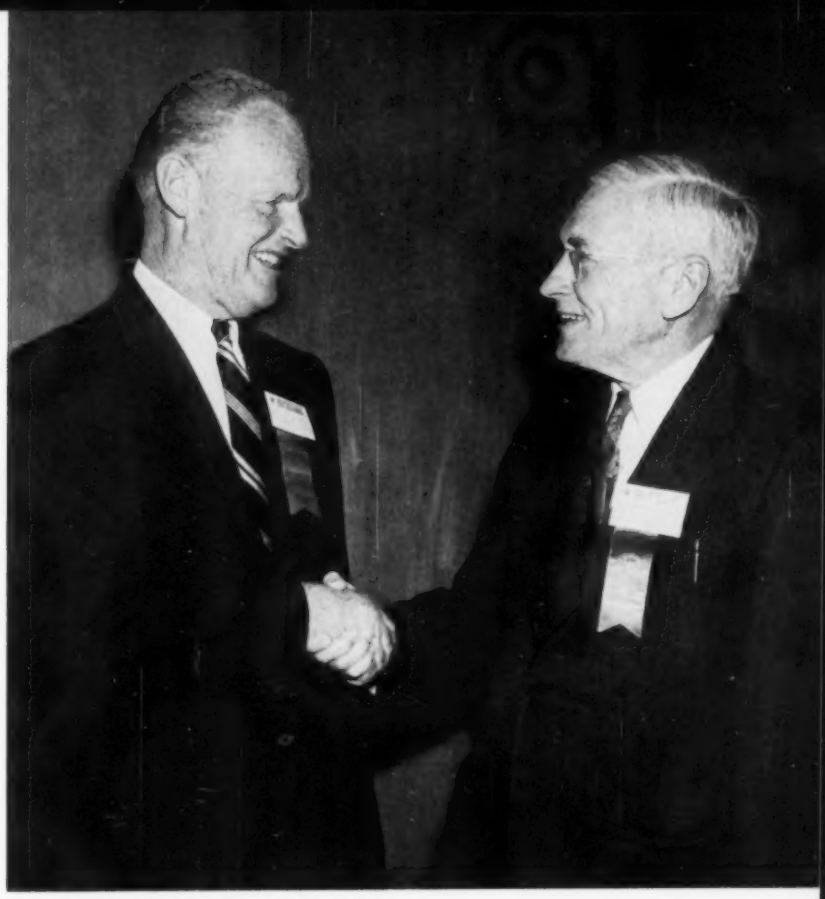
During Tuesday there were sessions on dislocations, mechanical properties, plutonium, gases in light metals, and basic oxygen steel. Many interesting papers were presented, some of which will be summarized in the May issue of JOURNAL OF METALS. A condensation of the paper, *Operation of the Basic Oxygen Furnaces at Aliquippa Works of J & L*, by D. R. Loughrey, will be found on p. 256 of this issue.

An important feature of Tuesday morning was the *Howe Memorial Lecture*, given before the Iron and Steel Division by C. E. Sims. Mr. Sims received the degree of Bachelor of Science from the University of Illinois in 1915 and his Master of Science de-

Our

New

Leaders . . .



Howard Pyle, AIME President, and John Chipman, who is Metallurgical Society President for 1959.

gree in 1916 from the University of Utah. Working with a number of metals-producing firms, he became technical director at Battelle Memorial Institute in 1947, retiring from that post last July. He is now a consultant at Battelle. Mr. Sims is author and co-author of 80 technical publications dealing mostly with ferrous metallurgy, nonmetallic inclusions, deoxidation, gases, and welding problems. His talk, the full text of which will appear in the June issue of the TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME, included discussion of the origin of exogenous inclusions, mechanical and chemical erosion of refractories, air oxidation, endogenous inclusions, distribution of inclusions and their effect, and the role played by various individual elements.

The Iron and Steel Division Annual Luncheon and Business Meeting was held on Tuesday at 12 noon, following the Howe Memorial Lecture. It was presided over by K. L. Fetters, Chairman of the Division. ISD award winners T. W. Crosta (*Robert W. Hunt Award*) and C. T. Marshall (*T. E. Johnson, Jr., Award*) were congratulated by the chairman. C. E. Sims was presented with a scroll to commemorate his selection as *Howe Memorial Lecturer*. J. L. Mauthe, chairman of the board of Youngstown Sheet & Tube Co., and this year's *Benjamin F. Fairless Award* winner, reminisced about *Half a Century of Steelmaking*.

All-Institute Session

A feature of Tuesday afternoon was the All-Institute Session during which Dr. Kinzel described in some detail the state of the AIME.

Featured speaker was Roger Revelle, director of Scripps Institute of Oceanography. In his talk, *Minerals Under the Oceans*, he pointed out that we know less about the floor of the Pacific Ocean than we do about the surface of the moon. He described the structural features of the Pacific which had been discovered by numerous expeditions. One feature is the flat-top sea mountains, thousands of them, under the ocean. The island of Bikini is one such mountain covered with a coral cap. Exploration of some of these undersea mountains has brought samples of manganese nodules to the surface. These have also been brought from the ocean floor at much deeper locations as well, and Dr. Revelle estimates that some 25 pct of the ocean floor is covered with such manganese nodules, analyzing from 14.5 to 44 pct Mn, up to 0.92 pct Co, to 1.43 Ni, and as high as 1.81 pct Cu. If a means could be developed to recover manganese nodules, it might mean that the manganese, cobalt, and nickel supply problems of the US —a have not nation in all these materials—could be solved. The Annual Business Meeting of the AIME followed the All-Institute Session. It included reports from the Secretary of the AIME as well as the Secretaries of the three constituent Societies and other officials. President Kinzel formally thanked members for their help during the past year and turned over his gavel to the 1959 President, Howard Pyle.

The Metallurgical Society dinner

The Annual Dinner of The Metallurgical Society of AIME was held on Tuesday evening at the St.

Francis Hotel. W. R. Hibbard, Jr., President, presided, first reading a telegram of congratulations from Kenneth Headlam-Morley, secretary of the Iron and Steel Institute of the UK. Greetings from the 1959 President of the AIME were brought by J. L. Gilson. K. L. Fetters, Chairman of the ISD, presented the *Robert W. Hunt Award* to T. W. Crosta for his paper, *Radioactive Study of Steel Surface Defects*, and the *J. E. Johnson, Jr., Award* to C. T. Marshall for development work on merchant iron furnace operations with particular emphasis on the use of slag byproducts and the cleaning of ferro manganese gas.

W. J. Harris, Jr., Chairman of the Institute of Metals Division, presented the *Mathewson Gold Medal* to John J. Gilman for a series of papers written between 1956 and 1958. And to the same recipient, J. L. Gilson presented the *Rossiter W. Raymond Memorial Award* for his paper, *Creation of Cleavage Steps by Dislocations*. Speaker of the evening was Robley C. Willams, assistant director, Virus Research Laboratory, University of California; his topic was *Structural Studies of Viruses*.
(Note: these awards as well as other awards of the various societies and divisions of AIME are summarized on p. 139 of the February issue of JOURNAL OF METALS—Ed.)

Wednesday

Technical sessions featured rare earths, zinc, alloy strengthening, more dislocations, the phase rule in extractive metallurgy, nickel, steelmaking, scale effects, and interfaces and surfaces. From the zinc session, *Some Physical Chemical Aspects of Zinc Blast Furnace Operation*, by Morgan and Lumsden, is to be found on p. — of this issue.

The Annual Business Meeting of the Institute of Metals Division was followed by the Annual IMD Lecture. Lecturer was Frederick Seitz, University of Illinois, who spoke on *The Effects of Irradiation Upon Metals*.

Dr. Seitz was born in San Francisco, receiving his B.A. in mathematics at Stanford University in 1932 and his Ph.D. in physics from Princeton in 1934. Largely associated with universities since that time, he joined the University of Illinois in 1949, and since 1957 he has been head of the Dept. of Physics. Professor Seitz, a member of many leading scientific organizations, is the author of 130 published technical papers.

Dr. Seitz' lecture, which will appear in full in the June issue of the TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME, emphasized that experiences over the past 15 years shows that metals have a higher stability under irradiation than other materials that have been tested. However, it was noted that metals do undergo definite changes during radiation, and Dr. Seitz pointed out changes in transition temperature of typical steels as an example.

Wednesday noon featured the Annual Stag Luncheon and Business Meeting of the Extractive Metallurgy Division. J. H. Kellogg, Division Chairman, presided. Since this was the 10th Anniversary of the EMD, all past-chairmen were seated at the head table. Dr. Kellogg presented the immediate Past-Chairman, Bruce Gonser, with a plaque expressing the appreciation of the Division for his work.

Gold Medal and Certificate for the EMD Award was presented to R. Schuhmann, Jr. and William A. Krivsky for their paper, *Thermodynamics of the Cu-Fe-S System at Matte Smelting Temperatures*. Luncheon speaker Granville S. Borden spoke on *Uncle Sam's Mineral Share Croppers*, making a strong plea for the continuation of the depletion allowance on mineral operations.

Annual banquet

The Annual Banquet was held at 7:00 pm on Wednesday at the Sheraton-Palace Hotel. Presentation of awards and honors immediately followed the dinner. These are outlined on p. 139 of the February issue of JOURNAL OF METALS. Actual presentations were made at many of the Society dinners, and there remained for President Kinzel to present the *James Douglas Gold Medal* to Clyde Williams, for merly of Battelle Memorial Institute and now head of an industrial research and management advisory firm. The medal was presented to Dr. Williams "For outstanding contributions in nonferrous metallurgy particularly through stimulating research and interest in the basic metallurgy and the use of both the common and less common metals."

John B. Knaebel was presented with *The William Lawrence Saunders Gold Medal*, "For his versatility and courageous leadership in pioneering, exploring, developing, and managing highly successful mining ventures as a leader among men—yet one of them." John T. Hayward was presented with the *Anthony F. Lucas Gold Medal* "For practical applications of scientific principles to drilling and production problems; resourceful development of the mud logging process; and outstanding contribution toward bringing Continental Shelf reserves within economic reach by successful design of a submersible drilling barge." James L. Mauthe was presented with *The Benjamin F. Fairless Award*, "For his early contributions to improved efficiency of blast furnace operations and masterful guidance of the steel company which he now heads."

Dr. Kinzel introduced the new AIME president, Howard C. Pyle, who spoke on how American business men must work to regain leadership in national affairs.

The last day . . . Thursday

The technical program of the meeting continued with session on alloy strengthening at elevated temperatures, interfaces and surfaces, basic science of steelmaking, refractories, chlorination processes, gas-metal research, pyrometallurgical processes, and uranium. Feature of the day was the first Extractive Metallurgy Division Lecture. It was given by consulting metallurgist W. J. Kroll, whose subject was *The Present State of Titanium Metallurgy*. Dr. Kroll stressed the importance of the role titanium technology has played in developing other branches of metallurgy. Chloride chemistry, welding under inert gases, vacuum pump design and construction, and vacuum casting of steel are a few of the fields that have benefited from research and development work that was originally done on titanium. Dr. Kroll's lecture will appear in a future issue of the TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME.

Thus, following five days solidly packed with technical sessions, luncheons, banquets, and committee meetings, to say nothing of an occasional view of San Francisco-by-night, AIME members pulled their winter coats back out of the closet and headed somewhat wearily for cooler climes, probably hoping to return before long to *Baghdad-by-the-Bay*.

AIME OFFICERS:

PRESIDENT—HOWARD C. PYLE

PAST-PRESIDENT—AUGUSTUS B. KINZEL

PRESIDENT-ELECT—JOSEPH L. GILLSON

VICE-PRESIDENTS—E. C. SABSON, THOMAS C. FRICK, WALTER R. HIBBARD, JR., ELMER A. JONES, JOHN C. KINNEAR JR., ROGER V. PIERCE

TREASURER—C. R. DODSON

SECRETARY—ERNEST KIRKENDALL

AIME STAFF:

ASST. SECRETARIES—J. B. ALFORD, H. N. APPLETON, J. C. FOX, R. W. SHEARMAN

ASST. TREASURER—JOHN LYNCH

AIME NEWS

13th New England Conference Meets in Hartford, Conn.

The program for the 13th Annual New England Regional Conference, sponsored by The Metallurgical Society, has been announced by D. Luther Martin, General Electric Co., Schenectady, chairman of the conference. This year's theme is *Melting, Continuous Casting, and Rolling of Copper and Aluminum Alloys.* The meeting will be held at the Statler Hotel, Hartford, Conn., on May 21st and 22nd, and will feature a new format for its technical sessions.

Affording an opportunity for fellowship, which highlights regional meetings, will be the banquet on May 21, at the Statler. Speaker of the evening will be S. V. Grancsay, curator of arms and armor at New York's Metropolitan Museum of Art, who will talk on *Historical Arms and Armor: Their Role in the Development of Metalwork.*

The new look in technical sessions calls for a paper on the fundamentals of each of the three processes which are the subject of the conference, followed by shorter papers and a panel discussion on practical aspects of each process.

Climaxing the 2-day meeting on Friday afternoon will be a plant tour of General Motors' New Departure div. in Bristol, Conn.

The technical program for the meeting is as follows:

Thursday, am: Session on Melting—Paper by D. R. Hull, The American Brass Co., Waterbury, Conn., followed by a panel discussion.

Thursday pm: Session on Continuous Casting—Paper by J. S. Smart, Jr., American Smelting & Refining Co., New York, followed by a panel discussion.

Friday am: Session on Rolling—Paper by W. A. Backofen, Massachusetts Institute of Technology, Cambridge, followed by a panel discussion.

Assisting the chairman in arrangements for the conference are R. P. Carreker, General Electric Co., Schenectady, program chairman, and R. S. Bray, Chase Brass & Copper Co., Waterbury, Conn., publicity chairman.

Names of the panel discussion members have not been announced.

Nuclear Journal Begins Publication in Europe

The *Journal of Nuclear Materials*, published by North-Holland Publishing Co., Amsterdam, will make its initial appearance in April 1959. A journal on metallurgy, ceramics, and solid state physics in the nuclear energy industry, it will be published temporarily on a quarterly basis. An annual volume of about 360 pages is in the planning stage.

JNM is to be entirely international in character. The editorial advisory board consists of representatives from many countries in all parts of the world.

Submission of papers or letters is invited. They should be written in English, French, or German, with a summary in the appropriate language. For long papers, extensive appendices are desirable. Authors who are contemplating the writing of a review are asked to correspond with one of the editors beforehand to avoid possible duplication.

Papers or letters may be sent to *R. W. Cahn, Dept. of Metallurgy, University of Birmingham, Birmingham 15, England; J. P. Howe, Atomics International, P.O. Box 309, Canoga Park, Calif.; or P. Lacombe, Centre de Recherches Metallurgiques de l'Ecole des Mines, Blvd. St. Michel 60, Paris VI, France.*

Subscription price is $18.00 (130 s., Gld. 68.50) per volume. Orders may be directed to *Journal of Nuclear Materials (Journal des Materiaux Nucleaires), North-Holland Publishing Co., P.O.B., 103, Amsterdam, The Netherlands.*

Metallurgical Society Announces Standing Committees for 1959

John Chipman, President of The Metallurgical Society, has announced the selection of the following individuals to serve as members of standing committees during his term of office.

Admissions Committee

Chairman—L. L. Seigle, manager of metallurgical research, Sylvania Electric Products Inc., Bayside, N. Y.

W. L. Brytczuk, associate director of research, American Metal Co. Inc., Carteret, N. J.

F. B. Foley, consulting metallurgist, International Nickel Co., New York.

T. D. Jones, chief lead refinery metallurgist, American Smelting & Refining Co., Barber, N. J.

Harold Margolin, associate professor of metallurgical engineering, New York University, New York.

Shadburn Marshall, director of metallurgical research, Air Reduction Co., Murray Hill, N. J.

(*Continued on page 289*)

Abstract Deadline for Fall Meeting

The Programs Committee for the Institute of Metals Division has announced that the deadline date for submission of abstracts to be considered for the 1959 Fall Meeting will be July 15. The abstracts should be between 200 to 300 words, and should be submitted in three (3) copies to: *IMD Programs Committee, The Metallurgical Society of AIME, 29 West 39th Street, New York 18, N.Y.*

The Fall Meeting will be held at the Morrison Hotel in Chicago, November 2-5. Further information on the Fall Meeting will appear in coming issues of JOURNAL OF METALS.

IMPORTANT McGRAW-HILL BOOKS

METAL FATIGUE

By George Sines, University of California, Los Angeles; and J. L. Waisman, Douglas Aircraft Company. *McGraw-Hill UCLA Engineering Extension Series.* 415 pages, $12.50.

The most rational exposition of fatigue of metals to be found in one book. The editors have sought the leading authority for each subject and put the key information into print. Critically selected bibliographies are provided, and the introduction includes a guide to fatigue literature, for those not thoroughly familiar with the field. The book presents a coordinated advanced treatment, by men who are experts, writing on their own specialties. Much of the subject matter is new.

PHYSICAL METALLURGY

By C. Ernest Birchenall, Princeton University. Ready in April.

The science of metals has taken enormous strides in the past few decades. In this book, the author takes cognizance of the new concepts, theories and experiments in order to produce an elementary text that "reflects in some measure the progress of recent years, the ferment and vitality of the field at present." To provide a sound underlying framework, the book has a strong scientific approach, at the expense of the engineering aspects. This exposition of fundamentals help to emphasize the unity underlying all aspects of the subject. In this respect the book departs significantly from all the other physical metallurgy texts and represents the long-awaited and much-needed approach to the subject.

CONSTITUTION OF BINARY ALLOYS

By Max Hansen, Metallgesellschaft A. G., Frankfurt-Main, Germany; in cooperation with Kurt Anderko, Metallgesellschaft A. G., Frankfurt-Main, Germany. *McGraw-Hill Metallurgy and Metallurgical Engineering Series.* Second Edition. 1305 pages, $32.50.

This revision and translation of the German work provides a source of reliable data concerning the constitution of binary alloy systems (phase diagrams) and the crystal structure of metallic phases. Widely scattered information in the world's metallurgical, physical, chemical, and crystallographical literature is analyzed and critically evaluated. About 9600 literature references were considered and are included. Contains 684 diagrams and 1286 systems.

Send for Copies on Approval

McGRAW-HILL BOOK COMPANY Inc.

330 West 42nd St. **New York 36, N. Y.**

Standing Committees

(*Continued from page 287*)

According to the Bylaws of The Metallurgy Society, the Admissions Committee "shall be responsible for reviewing the qualifications of candidates for membership and presenting the names of recommended candidates through the Secretary, AIME, to the Board of Directors of AIME for approval."

Education Committee

Chairman—T. A. Read, professor, Dept. of Mining and Metallurgical Research, University of Illinois, Urbana, Ill.

C. T. Evans, vice president, Universal Cyclops Steel Corp., Bridgeville, Pa.

W. R. Hibbard, Jr., manager, alloy studies research, General Electric Co., Schenectady, N. Y.

(*Continued on page 291*)

Refractory Metals Session Scheduled at Fall Meeting

The Refractory Metals Committee of the Institute of Metals Div. is planning two technical sessions on refractory metals during the Fall Meeting of The Metallurgical Society, held together with the National Metals Congress in Chicago, Nov. 2 to 6, 1959. These sessions will be devoted to the presentation of new research findings on the refractory metals. The theme of these sessions will be the *Preparation of Refractory Metals and Their Properties*, as related to purity, structure, and those variables that enter into the preparational techniques.

Papers are invited for presentation at the above sessions; a brief abstract should be submitted no later than May 31, 1959, to *R. W. Fountain, Refractory Metals Committee AIME, Union Carbide Metals Co. P. O. Box 580, Niagara Falls, N. Y.*

Authors who wish to do so may, in addition, submit three copies of their paper to the Editor of TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME.

Program Changes For Semiconductors

The following changes have been announced in the program for invited sessions of the Conference on Properties of Elemental and Compound Semiconductors, to be held in Boston at the Statler Hotel, August 31st to September 2nd.

An additional paper in the session on Elemental Semiconductors will be on *The Roll and Dislocations in Device Properties*, by L. E. Miller of Bell Telephone Laboratories. An additional paper for the session on Compound Semiconductors will be *Materials for Thermoelectric Applications*, by Robert Heikes of Westinghouse Electric Corp.

AROUND THE SECTIONS

• **Colorado** section gathered at the University Club in Denver on February 19th to hear Thomas C. Hiestand present a resume on depletion. Mr. Hiestand emphasized the fact that the derivation of depletion is in the title to real property and not in a dispensation of government.

• **Eastern North Carolina** subsection heard Philip M. Brown, district geologist, Groundwater branch, US Geology Survey, in Durham on February 21st. Mr. Brown spoke on *The Increasing Importance of Groundwater Management in our Expanding Society.*

• **El Paso** section learned of the *Ups and Downs of Mexico* from Tom Clendenin, chief geologist of the Mexican dept., American Smelting & Refining Co. Mr. Clendenin was guest speaker at the February 11th meeting.

• **Lima, Peru** section, 63 members and guests attending, participated in a *Symposium on Geology of Peruvian Nonferrous Metal Deposits*, at the Hotel Bolivar on February 18th. Questions and answers were taped.

• **Mexico** section commemorated Legion of Honor Section members Alexander W. Edelen and Hugh Rose. At the Jaunary meeting new officers were elected for the coming year: S. F. Trevino, president; Enrique Madero, Sr., vice president; J. T. Carty, secretary and treasurer. Three movies, *Launching of Atlas Score, Voyage of the Nautilus*, and *Behind the Ticker Tape*, were shown.

• **Niagara Frontier** section elected their officers on January 28th at the Red Coach Inn in Niagara Falls: chairman, W. W. Stephens; vice chairman, C. H. Emery; secretary, J. D. Roach; treasurer, A. L. Cerda; directors, J. H. Brennan, B. E. Field, D. C. Sturges, M. C. Udy, S F. Urban, T. J Voll.

• **Oregon** section announced its new officials at the January 16th meeting: chairman, D. H. Johnson; vice chairman, S. L. Sampson; secretary-treasurer, F. X. Cappa.

• **San Francisco** section welcomed its incoming officers at the January meeting in the Engineers Club and learned of *Mining & Milling at the Lucky Mc Mine, Wyoming* from guest speaker John S. Anderson, manager, Utah Mining Corp. and Utah Development Corp. Mr. Anderson covered all phases of mining and ore treatment, using colored slides to illustrate many phases of the operation.

• **Southwest Alaska** section met in Anchorage on January 19th. Earl Beestline, Dean of Mining School, University of Alaska, presented a short talk on the Universtiy and reported that there were 80 students enrolled—65 pct in geology, 25 pct in mining, and 3 pct in metallurgy.

Powder Metallurgists See Film in New York

The January meeting of the Powder Metallurgy Group, New York section, AIME, was held on February 5th at the Brass Rail Restaurant in New York. About 55 members attended the dinner which was followed with a *Report on the Status of Metal Powder Industry in 1958*, by Kempton H. Roll, executive secretary, the Metal Powder Industries Federation.

The regular program consisted of a M. W. Kellogg Co. film, *Sponge Iron—The HyL Process*, and two films presented by the Linde Company, *Powder Washing* and *Powder Lancing.*

This program departed from the usual emphasis on compacting and sintering of metal progress in an effort to illustrate other aspects of the metal powder industry.

The Kellogg film was presented by Mr. Robert Lawrence, Jr., who answered numerous questions about the HyL Process. Mr. C. B. Milton of Linde Co. presented the films on powder washing and powder lancing.

Nuclear Technology Conference Planned

Armour Research Foundation of Illinois Institute of Technology and Nucleonics magazine, in cooperation with the U. S. Atomic Energy Commission, will sponsor an Industrial Nuclear Technology conference at the Morrison Hotel, Chicago, from September 22nd through 24th.

Dr. Leonard Reiffel, director of physics research at Armour Research Foundation, and J. D. Luntz, editor of Nucleonics, are co-chairmen of the conference. Inquiries may be addressed to *Industrial Nuclear Conference, Armour Research Foundation, 10 W. 35th St., Chicago 16, Ill.*

New from Addison-Wesley

ELEMENTS OF MATERIALS SCIENCE—An Introductory Text for Engineering Students

by LAWRENCE H. VAN VLACK, *University of Michigan*

This textbook offers an introduction to engineering materials, on an elementary level, *for all students of engineering.* Its aim is to give the prospective engineer, regardless of his future field of specialization, a basic understanding of the structure of materials and the conditions under which they will be used. Both metals and nonmetals are considered, and the author has attempted to use real rather than idealized engineering materials by way of illustrative examples.

Since properties are related to the structure of the material, a background of introductory chemistry and physics is used to develop the structural concept; in addition, consideration is given to the effects of service environment upon the structure and properties. Introductory college mathematics is sufficient for the study of the book. It is anticipated that this text will be used at the *third-fifth semester level* of the college curriculum; when taught at this level it provides a background for subsequent engineering design and analysis courses.

c. 480 pp, 550 illus, 1959—$8.50

In the Addison-Wesley Series in Metallurgy and Materials, Morris Cohen—Consulting Editor

---

ELEMENTS OF PHYSICAL METALLURGY

By A. G. Guy, Purdue University

A thoroughly revised and expanded new edition of a widely used textbook for introductory courses in physical metallurgy.

529 pp, 297 illus, Second Edition 1959—$9.50

FUNDAMENTAL ASPECTS OF REACTOR SHIELDING

By Herbert Goldstein, Nuclear Development Corporation of America

An exposition of the fundamental shielding processes which serve as the basis for design of any reactor shield.

412 pp, 95 illus, 1959—$9.50

CONSTITUTIONAL DIAGRAMS OF URANIUM AND THORIUM ALLOYS

By Frank A. Rough and Arthur A. Bauer, Battelle Memorial Institute

A compilation of United States and United Kingdom uranium and thorium constitutional diagrams.

153 pp, 1959—$5.00

Four of the twelve volumes in the Geneva Atoms-for-Peace Presentation Set, 1958. Detailed brochure available upon request.

URANIUM ORE PROCESSING

Edited by J. W. Clegg and D. D. Foley, Battelle Memorial Institute

448 pp, 109 illus, 1958—$7.50

THORIUM PRODUCTION TECHNOLOGY

By F. L. Cuthbert, National Lead Company of Ohio

303 pp, 76 illus, 1958—$6.50

PHYSICAL METALLURGY OF URANIUM

By A. N. Holden, General Electric Company, Vallecitos Atomic Laboratory

262 pp, 155 illus, 1958—$5.75

PROJECT SHERWOOD—THE U. S. PROGRAM IN CONTROLLED FUSION

By Amasa S. Bishop, U. S. Atomic Energy Commission

216 pp, 50 illus, 1958—$5.75

ADDISON-WESLEY PUBLISHING COMPANY, INC., Reading, Massachusetts U.S.A.

Proposed Revisions in AIME Bylaws

The following revisions in the AIME Bylaws will be voted upon at the Board of Directors meeting, June 23, 1959:

Article V

Section 10. *Salary Committees.*

(a) *Formation of Committee.* The Salary Committee shall consist of five members including the Treasurer of AIME, the Secretary of AIME, two members at large, to be appointed by the President of AIME, who are experienced in personnel and wage administration, and the President of AIME as an ex-officio member. The members at large shall be appointed for the term of two years, and the President, Treasurer and Secretary of the Institute shall be maintained as members during their terms of office.

(b) *Presiding Officer.* The Chairman of this Committee shall be the Treasurer of the AIME and in his absence the Secretary of AIME.

(c) *Committee Meetings.* Meetings of the Committee shall be called by the Chairman of the Committee at such times as the Chairman may deem necessary.

(d) *Quorum.* Any three members of this Committee shall constitute a quorum.

(e) *Minutes of Meetings.* The Committee shall elect one of its members as Secretary for the keeping of minutes to be presented to the AIME Board of Directors or Executive Committee at its next meeting.

Section 11. *Pension Trustees.*

(a) *Appointment of Trustees.* The Pension Trustees shall consist of five members of AIME, including the Treasurer of AIME, the Secretary of AIME, two members at large, to be appointed by the President of AIME, who are experienced in employee pension programs, and the President of AIME as an ex-officio member. The members at large shall be appointed for the term of two years. The Treasurer, Secretary and President of AIME shall be maintained as members during their term of office.

(b) *Presiding Officer.* The Chairman of the Trustees shall be one of its members, duly elected by the Trustees at the first meeting following the AIME annual meeting in February of each year, such meeting to be called by the then Chairman of the Pension Trustees.

(c) *Trustees Meetings.* Meetings of the Pension Trustees shall be called by the Chairman at such times as he may deem necessary.

(Continued on page 292)

STANDING COMMITTEES (Continued from page 289)

T. B. King, associate professor, Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

M. E. Nicholson, professor, Dept. of Metallurgy, University of Minnesota, Minneapolis.

H. W. Paxton, professor, Dept. of Metallurgical Engineering, Carnegie Institute of Technology, Pittsburgh.

Paul Queneau, assistant to the vice president, International Nickel Co., New York.

A. W. Schlechten, professor, Dept. of Metallurgical Engineering, Missouri School of Mines, Rolla, Mo.

Reinhardt Schuhmann, Jr., professor, Dept. of Metallurgical Engineering, Purdue University, Lafayette, Ind.

O. C. Shepard, professor, Dept. of Metallurgical Engineering, Stanford University, Stanford, Calif.

The Education Committee "shall devise a program to promote high standards in the education of metallurgists and metallurgical engineers."

Finance Committee

Chairman—A. W. Thornton, asst. to vice president operations, National Tube div., U. S. Steel Corp., Pittsburgh.

T. D. Jones, chief lead refinery metallurgist, American Smelting & Refining Co., Barber, N. J.

A. R. Lytle, vice president, research, Union Carbide Metals Co., New York.

"The Finance Committee shall prepare the annual budget, and examine, plan for, and submit recommendations concerning the financial condition and welfare of the Society for consideration of the Board of Directors."

Robert Lansing Hardy Gold Medal Committee

Chairman—H. R. Spedden, Union Carbide Ore Co., New York.

H. B. Emerick, director, technical services, Jones & Laughlin Steel Corp., Pittsburgh.

C. L. McCabe, professor, Carnegie Institute of Technology, Pittsburgh.

R. L. Smith, Franklin Institute, Philadelphia.

This Committee is responsible for selecting a winner of the Robert Lansing Hardy Gold Medal each year.

Membership Committee

Chairman—J. H. Keeler, liaison scientist, General Electric Co., Schenectady, N. Y.

E. C. Rudolphy, chief development metallurgist, U. S. Steel Corp., Chicago.

A. W. Schlechten, professor, Dept. of Metallurgical Engineering, Missouri School of Mines, Rolla, Mo.

J. B. Newkirk, research metallurgist, General Electric Co., Schenectady, N. Y.

The Membership Committee "shall be responsible for the coordination of membership activities."

Committee on the Metallurgical Profession

Chairman—Morris Cohen, professor, Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

H. B. Emerick, director, technical services, Jones & Laughlin Steel Corp., Pittsburgh.

J. H. Hollomon, manager, metallurgy and ceramic research, General Electric Co., Schenectady, N. Y.

C. C. Long, director of research, St. Joseph Lead Co., Monaca, Pa.

J. P. Nielsen, professor, Dept. of Metallurgical Engineering, New York University, New York.

W. O. Philbrook, professor, Dept. of Metallurgical Engineering, Carnegie Institute of Technology, Pittsburgh.

R. J. Raudebaugh, head, ferrous alloy section, research laboratory, International Nickel Co., Bayonne, N. J.

G. A. Roberts, vice president, technology, Vanadium Alloys Steel Co., Latrobe, Pa.

A. W. Schlechten, professor, Dept. of Metallurgical Engineering, Missouri School of Mines, Rolla, Mo.

David Swan, director of research, Linde Co., New York.

A. W. Thornton, asst. to vice president, operations, National Tube div., U. S. Steel Corp., Pittsburgh.

The Committee on the Metallurgical Profession "shall promote high standards in the profession of metallurgy and metallurgical engineering, and shall have the authority to cooperate with organizations having similar objectives."

Nominating Committee

Chairman—W. R. Hibbard, Jr., manager, alloy studies research, General Electric Co., Schenectady, N. Y.

H. B. Emerick, director, technical services, Jones & Laughlin Steel Corp., Pittsburgh.

W. J. Harris, Jr., executive director, Materials Advisory Board, National Academy of Science-National Research Council, Washington.

J. C. Kinnear, Jr., general manager, Nevada Mines div., Kennecott Copper Corp., McGill, Nev.

J. S. Marsh, manager of research, Bethlehem Steel Co., Bethlehem, Pa.

C. E. Sims, technical director, ret., Battelle Memorial Institute, Columbus.

David Swan, vice president, Linde Co., New York.

P. T. Stroup, asst. director of research, Aluminum Co. of America, New Kensington, Pa.

The Nominating Committee has the responsibility of selecting men of caliber for officers of The Metallurgical Society and for positions on the AIME Board of Directors.

(Continued on page 293)

Instrumentation and Control Conference Set for April 14th

The Industrial Instrumentation and Control conference, scheduled for April 14th and 15th on the campus of the Illinois Institute of Technology, Chicago, will discuss measurement techniques as one of its major topics.

Sponsored by the Armour Research Foundation of ITT, in cooperation with the Professional Group on Industrial Electronics, and the Institute of Radio Engineers, the conference will highlight an address by Dr. Montgomery Phister, Jr., director of engineering, Thompson-Ramo-Wooldridge Products Co., on *Digital Control Systems, Present and Future*. R. W. Bull, supervisor of electron instrumentation at Armour is the conference chairman.

PERSONALS

H. Y. Hunsicker has moved from the Alcoa offices in Cleveland to New Kensington, Pa. with added research laboratory responsibilities.

Karl L. Fetters has been elected vice president, research and development, Youngstown Sheet & Tube Co.

Hans Conrad is now supervisory engineer of the deformation and fracture group of the metallurgy dept., Westinghouse Research Laboratories. He is responsible for basic studies on the mechanisms of deformation and fracture of materials.

John N. Ludwig, Jr., formerly with Electro Metallurgical Co., is supervisor of metallurgical services of The International Nickel Co. Inc. Mr. Ludwig's office is in Pittsburgh.

Edward A. Loria has been appointed development manager, high temperature and corrosion resistant alloys for Climax Molybdenum Co. Mr. Loria was formerly product metallurgical engineer, titanium and vacuum metals, Crucible Steel Co. of America.

Charles W. Cravens, has been named district manager of Republic Steel Corp. He had been assistant district manager prior to his promotion. Mr. Cravens joined Republic in 1942 as a senior melter in the tilting and electric furnace department.

Raymond G. Reiff received an appointment as foundry service manager of the American Metallurgical Products Co. Inc., of Pittsburgh. He had been with the Dearborn Iron Foundry, Ford Motor Co. as a supervisor of the Quality Control Laboratories.

AIME Bylaws

(*Continued from page 291*)

(d) *Quorum.* Any three of the Trustees shall constitute a quorum.

(e) *Minutes of Meetings.* The Trustees shall elect one of their members as Secretary for the taking of minutes to be presented to the AIME Board of Directors or Executive Committee at its next meeting.

Change in Rules

Article IV-A

Section 3. *Duties of the Board of Directors.* **Rule 8.** *Fixing Institute Salaries.*

(a) *Salaries of $9000 or more per year.* All requests for changes in salaries of employees being paid $9000 or more per year shall be submitted by the Board of Directors of the constituent Societies to the AIME Salary Committee for review. The Committee shall submit all such requests with comments and recommendations to the AIME Board of Directors or Executive Committee for action at its first meeting following such request. No salaries may be set for a period longer than one year.

Article V

Section 10. *Salary Commitee.* **Rule 1.** *Duties of the committee.*

(a) The Salary Committee shall, when requested by the AIME Board of Directors or any constituent Society Board of Directors, review salaries and wages of AIME employees receiving $9000 or more per year. Recommended changes in salaries shall be submitted to the AIME Board of Directors or Executive Committee at their next meeting for final action.

Section 11. *Pension Trustees.* **Rule 1.** The Trustees shall from time to time review the status of the Institute pension plan and recommend alterations in this plan to the Board of Directors of AIME.

Rule 2. The Trustees shall from time to time review the status of all individual employees under the AIME pension plan and recommend changes to the Board of Directors.

Rule 3. Requests for extension or reduction of service of any AIME employee beyond or before normal retirement date shall be considered by the Pension Trustees and their recommendations submitted to the AIME Board of Directors.

Rule 4. Pension Trustees shall periodically consider or review the employees health and insurance programs to insure maximum benefits being made available and maintained by AIME employees.

Education

(*Continued from page 234*)

will contribute materially to their future teaching. Approximately 400 teachers will be chosen from secondary schools; the remaining 150 will be picked from junior colleges and small colleges without appropriate research facilities.

► **MIT** has scheduled a one week course from July 20th to 24th on *scientific and engineering reports.* The course is designed to help scientists, engineers, and technical writers improve their ability to handle varied reporting assignments. Individual editorial conferences with the staff will be arranged. Tuition is $175. For details, *see MIT address above.*

► **The Pennsylvania State University** will hold a *research and development management seminar* from July 5th to 10th. Lecture and workshop sessions will center around development of administrative skills, the role of management, leadership, motivation, communication, training, rating, and other human considerations. Address inquiries to *Extension Conference Center, The Pennsylvania State University, University Park, Pa.*

TECHNICAL FILMS

► **The AEC** has announced that 45 technical-level, professional motion pictures first screened last September in Geneva, at the Second International Conference on the Peaceful Uses of Atomic Energy, are available for loan and sale.

Inquiries may be made to *Public Information Service, US Atomic Energy Commission, Washington 25, D. C.*

Powder Metallurgy Show Scheduled for April 20th

The 1959 Powder Metallurgy Show will be held in Detroit on April 20th to 22nd at the Sheraton-Cadillac Hotel in Detroit.

The meetings and the show will stress new methods and parts made with special properties, as well as demonstrate new advances in hardness, strength, lubricating qualities, and close tolerance. Mr. Kempton H. Roll, executive secretary of the Metal Powder Industries Federation, states that "engineers and designers should find the show especially rewarding because of the new fields encompassed in both the exhibits and technical papers."

Standing Committees

(Continued from page 291)

Programs Committee

Chairman-Reinhardt Schuhmann, Jr., professor, Metallurgical Engineering Div., Purdue University, Lafayette, Ind.

J. H. Jackson, manager, dept. of metallurgy, Battelle Memorial Institute, Columbus.

C. W. Sherman, Jones & Laughlin Steel Corp., Pittsburgh.

W. W. Stephens, manager of manufacturing, Carborundum Metal Co. Inc., Akron, N. Y.

The Programs Committee "shall coordinate program plans and provide for such joint programs among the Divisions as are deemed advisable."

Publications Committee

Chairman—Robert Maddin, professor, Dept. of Metallurgy, University of Pennsylvania, Philadelphia.

D. J. Carney, division superintendent, steel production, U. S. Steel Corp., Duquesne, Pa.

J. C. Fulton, associate director of research, Allegheny Ludlum Steel Corp., Brackenridge, Pa.

J. H. Hollomon, manager, metallurgy and ceramic research, General Electric Co., Schenectady, N. Y.

T. B. King, professor, Dept. of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

C. C. Long, director of research, St. Joseph Lead Co., Monaca, Pa.

W. O. Philbrook, professor, Dept. of Metallurgical Engineering, Carnegie Institute of Technology, Pittsburgh.

J. D. Sullivan, technical director, Battelle Memorial Institute, Columbus.

David Swan, director of research, Linde Co., New York.

F. L. Vogel, member technical staff, Bell Telephone Laboratories, Murray Hill, N. J.

The Publications Committee "shall determine publication policies of the Society, shall have authority to accept or reject papers to be published in the publication(s) of the Society, and shall have the duty of preparing and maintaining a publications budget."

NECROLOGY

Date Elected	Name	Date of Death
1920	Bancroft, J. A.	Unknown
1934	Banz, Frank X.	Nov. 25, 1958
1942	Borgeson, A. C.	Dec. 13, 1958
1924	Camsell, Charles (Honorary Member)	Dec. 19, 1958
1956	Daniels, Charles W.	Jan. 30, 1959
1928	del Giudice, Guy R.	Jan. 23, 1959
1942	Drake, N. D.	Unknown
1914	Fell, Harold B.	Jan. 12, 1959
1952	Hayden, Thomas A.	Dec. 15, 1958
1935	Hayes, L. S.	Jan. 31, 1959
1920	Hirschberg, Chas. A.	August 1958
1917	Jardine, F. M.	Dec. 11, 1958
1900	Lakenan, C. B. (Legion of Honor)	Jan. 19, 1959
1938	Mullen, John T., Jr.	Jan. 18, 1959
1936	O'Brien, R. E.	Jan. 9, 1959
1917	Parker, D. J.	Nov. 21, 1958
1952	Rasor, James H.	Jan. 24, 1959
1914	Reger, David B.	Sept. 10, 1958
1921	Sabin, D. J.	Apr. 1, 1958
1945	Snarr, F. Earle	Jan 16, 1959
1917	Sparks, Harry E.	Dec. 25, 1958
1928	Sturges, Lee	Unknown

OBITUARIES

Frank X. Banz (member 1934), died on Nov. 25, 1958. Mr. Banz, who had been retired for some time, graduated from Maryland Institute in 1905. He was associated for many years with the Chile Exploration Co., Chuquicamata, Chile. His home was in Baltimore.

Thomas A. Hayden (member 1952) passed away on Dec. 15, 1958. Mr. Hayden was open hearth consultant to the Quigley Co. Inc. at the time of his death. Prior to his position as consultant, he had been associated with Jones & Laughlin Steel Corp.

MEMBERSHIP

Proposed for Membership
Metallurgical Society of AIME

Total AIME membership on Feb. 28, 1959 was 30,889; in addition 3,974 Student members were enrolled.

ADMISSIONS COMMITTEE

L. L. Seigle, Chairman; W. L. Bryteczuk; F. B. Foley; T. D. Jones; Harold Margolin; Shadburn Marshall.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

Balog, Edward G., Fairfield, Ala.
Bauer, Raymond A., Olympia Fields, Ill.
Bessen, Irwin I., Pittsburgh.
Drake, Charles W., Ontario, Can.
Eisenberg, Richard F., Rochester.
Gamble, Jaye S., McKeesport, Pa.
Garibotti, Domenick J., Chicago.
Hager, William F., Milwaukee.
Huck, George M., San Francisco.
Ingraham, Thomas R., Ottawa, Ont., Can.
Isomura, Kiyoshi, New York.
Johnston, Thomas L., Hopkins, Minn.
Jones, Robert G., Albany, Ore.
Kimberley, John L., New York.
Klapper, Joseph A., New York.
Kron, Robert O., Salt Lake City.
Lyle, Edwin B., Salt Lake City.
McArdle, Gordon D., Detroit.
McClure, Roger N., Rockwood, Tenn.
McConnell, Marion P., Harrison, N. J.
Scheidemantel, Clyde A., Cleveland.
Scholz, Frank H., Palmerton, Pa.
Seitanakis, George P., Natrona Heights, Pa.
Trapp, Robert H., Blairsville, Pa.
Triffleman, Benard, Fairlawn, N. J.
White, Denis W. G., Ottawa, Ont., Can.
Yakel, Harry L., Jr., Oak Ridge.

Associate Members

Kern, Harry B., Solon, Ohio.
Lewin, Richard H., St. Louis, Mo.
Wheeler, Frank R., Detroit.

Junior Members

Armstrong, William J., W. Simsbury, Conn.
Arora, Rajendra K., Pittsburgh.
Belyea, Harry G., Kingston, Ont., Can.
Daugherty, Charles A., Torrance, Calif.
Deweck, Jean, Vilvorde, Belgium.
Eiss, Abraham L., New Rochelle, N. Y.
Faunce, Richard L., Cleveland.
Hardcastle, Kendrick C., III, Tampa, Fla.
Harrison, Charles H., Calumet City, Ill.
Hathaway, Jerome M., Massillion, Ohio.
Joiret, Victor, Vaux-Lez-Liege, Belgium
Keith, George H., East Orange, N. J.
Phatak, Vidyadmar Y., Pittsburgh.
Schafer, Robert J., Cleveland.
Steele, Roger K., Springfield, Mass.

REINSTATEMENT

Member

Kuczynski, George C., Notre Dame, Ind.

CHANGE OF STATUS

Junior to Member

Perkins, Edward C., Boulder City, Nev.
Steinbrenner, Walter L., Pittsburgh.

Junior to Member

Harris, Leonard, La Oroya, Peru.

Associate to Member

Adams, Clyde M., Lexington, Mass.
Clare, L. P., Towanda, Pa.
Cooper, Herbert J., Short Hills, N. J.
Hayashi, Masami, Salt Lake City.
Juergens, Raymond J., St. Louis, Mo.
Lenhart, Robert E., Schillington, Pa.
Moorhead, Paul E., Niles, Ohio.
Nelson, Russell C., Towanda, Pa.
Solomon, Alexander, Detroit.
White, Jack L., San Diego.

RE-ELECTION

Bartholomew, K. R., Pontiac, Mich.

PROFESSIONAL SERVICES

MAX STERN
Consulting Engineer
Expert for Scrap Recovery and Shipwrecking—Modernization of Plants and Yards for Ferrous and Nonferrous Metal Scrap
10 East 40th St. New York 16, N. Y.

DR. E. TSUTSUMI
Registered Japanese Patent Attorney & Consulting Engineer
PATENT MATTERS handled . . . TECHNICAL TEXT translated from Japanese into English or vice versa: 2¢ an English word.
Central P.O. Box 1545 Tokyo, Japan

H. L. TALBOT
Consulting Metallurgical Engineer
Extraction and Refining of Base Metals Specializing in Cobalt and Copper
Room 911, 209 Washington St. Boston 8, Mass.

EDWARD G. VOGT
Consulting Chemical-Metallurgical Engineer
Applied Statistics
Experimental Designs Data Analysis
1130 Woodlawn Street, Bethel Park, Pa.
Telephone: TEnnyson 5-5241 (Pittsburgh)

Coming Events

Apr. 2-3, AIME National Conference on Physical Metallurgy of Stress Corrosion Fracture, Mellon Institute, Pittsburgh, in cooperation with the Electrochemical Society, American Society for Testing Materials, and National Society of Corrosion Engineers.

Apr. 5-10, Fifth Nuclear Congress, Cleveland Auditorium, Cleveland.

Apr. 6-8, AIME 42nd National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Jefferson Hotel, St. Louis.

Apr. 16-18, AIME Northwest Regional Conference, Olympic Hotel, Seattle, Wash.

Apr. 22-26, Annual spring meeting of the Metal Treating Institute, Hollywood Beach Hotel, Hollywood, Florida.

Apr. 27-30, AIME International Symposium on the Physical Chemistry of Process Metallurgy, Penn-Sheraton Hotel, Pittsburgh.

May 4, AIME, NOHC Chicago Local Section, Spring meeting at Phil Smidt's Restaurant, Hammond, Ind.

May 6, AIME, New York Section, joint meeting of Physical metallurgists and powder metallurgists. Laboratory tour followed by dinner-meeting, Stevens Institute of Technology, Hoboken, N. J.

May 14, AIME, NOHC Cleveland Section, meeting, Rockside Gardens, Cleveland. Topic: Basic Roofs.

May 21-22, AIME New England Regional Conference, Statler Hotel, Hartford, Conn.

June 5, AIME, NOHC Southern Ohio Section. Golf Outing, Summit Hills Country Club, Fort Mitchell, Kenton County, Ky.

June 10, AIME, NOHC Northern Ohio Section, annual golf party at the Squaw Creek Country Club, Youngstown, Ohio.

June 15, AIME, NOHC Pittsburgh Section, Golf Party, Churchill Valley Country Club.

June 15, AIME, NOHC Eastern Section, plant visit to E. J. Lavino & Co. and G. & W. H. Corson Inc.; golf party at Plymouth Country Club, Plymouth Meeting, Pa.

June 20, AIME, NOHC Cleveland Section, Dinner-Dance, Lake Shore Hotel, Cleveland.

Aug. 31-Sept. 2, Semiconductors Conference, Statler Hotel, Boston, Mass.

Oct. 16-17, AIME, NOHC Southern Ohio Section, Fall Meeting, Deshler-Hilton Hotel, Columbus, Ohio.

Nov. 2-6, Fall Meeting of The Metallurgical Society of AIME, Morrison Hotel, Chicago.

Nov. 6, AIME, NOHC Pittsburgh Section, Off-the-Record Meeting, Penn-Sheraton Hotel, Pittsburgh.

Dec. 2-4, AIME 17th Electric Furnace Steel Conference, Hotel Cleveland, Cleveland, Ohio.

Feb. 14-18, 1960, AIME Annual Meeting, Hotel McAlpin and Hotel Statler, New York.

Apr. 4-6, 1960, AIME 43rd National Open Hearth Steel Conference and Blast Furnace, Coke Oven, and Raw Materials Conference, Palmer House, Chicago.

June 13-15, 1960, first International Powder Metallurgy Conference, Hotel Biltmore, New York, under joint auspices of AIME and MPI.

Nov. 30-Dec. 2, 1960, 18th Electric Furnace Steel Conference, Morrison Hotel, Chicago.

ADVERTISER'S INDEX

American Optical Co. *
The J. G. Kelly Co., Inc.

Argonne National Laboratory *
Grant, Jacoby Studios, Inc.

Bailey Co., Wm. M. *
Downing Industrial Adv., Inc.

Baker Co., The J. E. 224
Adams Associates, Inc.

Basic, Incorporated 232
Duffy, McClure & Wilder, Inc.

Bell Telephone Labs. 254
N. W. Ayer & Son, Inc.

Buehler Ltd. *
Kreicker & Meloan, Inc.

Carborundum Co. *
Carborundum Metals Co. Div.
Comstock & Co.

Consolidated Electrodynamics Corp. 238
Rochester Div.
Wolff Associates, Inc.

Corhart Refractories Co. 225
Doe-Anderson Adv. Agency

Ferro Engineering Co. *
C. A. Reece Ind. Publicity

Frankel Co., Inc. 230
Denham & Co.

General Refractories Co. 223
Lewis & Gilman, Inc.

Great Lakes Carbon Co. 211
Davis, Parsons & Strohmeier, Inc.

Harbison-Walker Refractories Co. 212, 213
Downing Industrial Adv. Inc.

Hevi-Duty Electric Co. 222
Bert S. Gittins Adv., Inc.

Illinois Clay Products Co. 218
Connor Assoc., Inc.

International Nickel Co. 220
Marschalk & Pratt

Island Creek Coal Sales Co. 235
Stockton-West-Burkhart Inc.

Kellogg Co., The M. W. *
Fuller & Smith & Ross Inc.

Latimer Co., Ira S. *
Henry H. Hook Adv.

Lectromelt Furnace Div. 231
McGraw-Edison Co.
The Griswold-Eshleman Co.

Leitz, Inc., E. *
L. W. Frohlich and Company

Lindsay Chemical Div. *
American Potash & Chem. Corp.
C. Franklin Brown, Inc.

Marshall Products Co. 210
Weber, Geiger & Kalat, Inc.

Michigan Chemical Corp. 208
Wesley Aves & Assoc.

Molybdenum Corp. of America *
Smith, Taylor & Jenkins, Inc.

Morgan Construction Co. 226
Davis Press, Inc., The

Ohio Ferro-Alloys Corp. Fourth Cover
Frease & Shorr Adv.

Philips Electronics, Inc. *
Anders Associates Adv.

Radio Corporation of America 2nd Cover
Al Paul Lefton Co., Inc.

Ramtite Co., The 214, 215
Leo P. Bott, Jr. Adv.

Research Specialties Co. *
Gerth, Brown, Clark & Elkus

Robinson Clay Product Co. 227
Norman Malone Assoc., Inc.

Smidth & Co., F. L. 209
The Stuart Co.

Stokes Corp., F. L. *
The Aitkin-Kynett Co.

Swindell-Dressler Corp. *
Downing Industrial Adv., Inc.

Sylvania Electro Products, Inc.
Chemical & Metallurgical Div. *
J. Walter Thompson Co.

Taylor Sons Co., The Chas. 217
The Keelor & Stites Co.

Union Carbide Metals Co., Div. 219, 228, 229
Union Carbide Corp.
J. M. Mathes, Inc.

United States Graphite Co., The *
Price, Tanner & Willox, Inc.

U. S. Steel Corp. *
Columbia-Geneva Steel Div.
Tennessee Coal & Iron Div.
U. S. Steel Supply Div.
U. S. Steel Export Co.
Batten, Barton, Durstine & Osborn, Inc.

Unitron Instrument Div. 233
United Scientific Co.
Larcom Randall Adv. Inc.

Utica Drop Forge and Tool *
Div. of Kelsey-Hayes Co.
Zimmer, Keller & Calvert, Inc.

Valley Mould & Iron Corp. 234

Walsh Refractories Corp. 236
Ralph Smith Adv. Agency

Wyman-Gordon Co. Third Cover
H. M. Cutler & Co., Inc.

Yawata Iron & Steel Co., Ltd. *
Dentsu Adv. Ltd.

* Previous issue.

forging a renaissance in COPPER

THE BETTMANN ARCHIVE

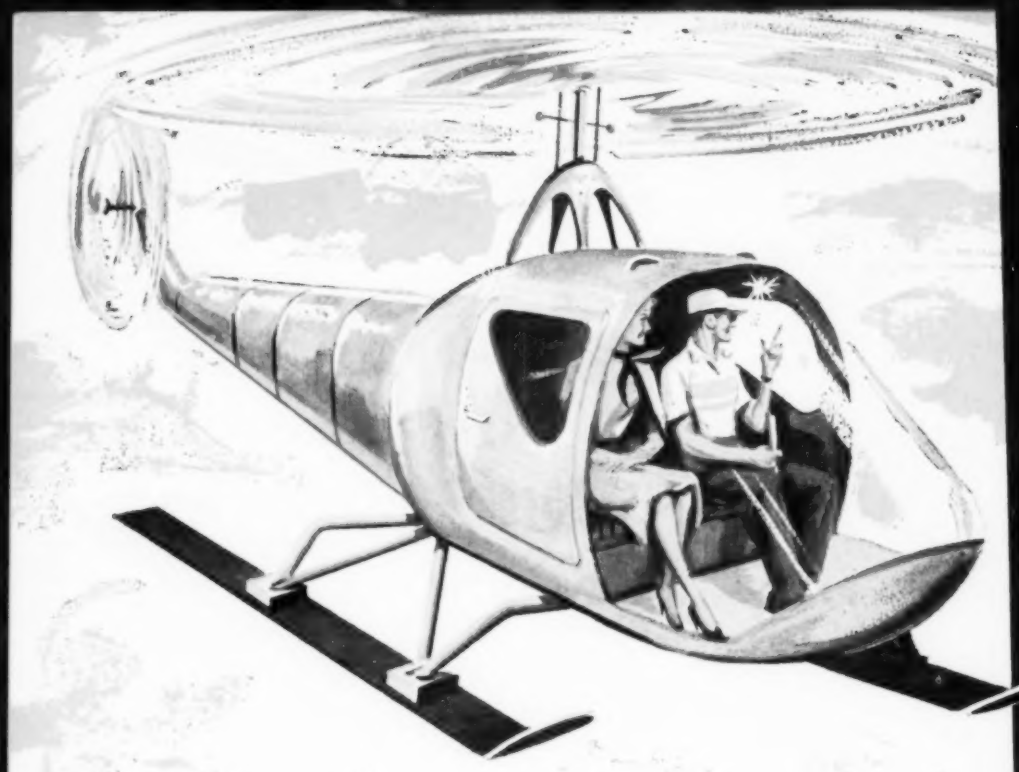
Forging "new metals" has been routine procedure at Wyman-Gordon for 75 years. Contrasting the modern marvels of metallurgical development is the oldest metal employed by man—copper. Here you see the largest copper closed die forging ever produced—a Re-entry Shield weighing 1875 pounds (67-1/2" x 21-1/2"). Unexcelled know-how, with the availability of the most modern forging equipment, assures the ultimate in forging quality to meet the constantly expanding demands of progress—man's quest for greater speeds and power in his unending exploration farther and farther into yesterday's unknown.

WYMAN-GORDON COMPANY

Established 1883

FORGINGS OF ALUMINUM • MAGNESIUM • STEEL • TITANIUM
Also Beryllium • Molybdenum • Columbium and other uncommon materials

WORCESTER 1, MASSACHUSETTS
HARVEY, ILLINOIS • DETROIT, MICHIGAN



CALCIUM SILICON

VALUABLE and VERSATILE!

Airborne jack-of-all-trades is the helicopter. Used for everything from mercy missions to eyes-in-the-sky reconnaissance, the extent of the whirly-bird's versatility seems limited only by the imagination.

Calcium silicon and calcium manganese silicon offer similar versatility to steel producers. Dependable deoxidizers and degassifiers, these calcium alloys are widely used in production of bearing, aircraft quality and stainless steels. They also are extensively used in production of both alloy and carbon steel castings to assure maximum physical properties. Calcium silicon is an excellent inoculant for low carbon, equivalent-high tensile cast irons.

Ohio Ferro-Alloys is a major producer of both calcium silicon and calcium manganese silicon. Stocks of lump and crushed sizes for furnace and ladle additions are maintained at our conveniently-located plants and warehouses. For information on how these alloys may benefit you, contact our nearest sales office.

QUALITY SERVICE DEPENDABILITY

Ohio Ferro-Alloys Corporation
Canton, Ohio

Boston, Birmingham, Chicago, Denver, Detroit, Houston, Kansas City, Los Angeles, Minneapolis, Philadelphia, Pittsburgh, Salt Lake City, San Francisco, Seattle, Vancouver, B. C.

FOR EXTRA CONVENIENCE

Many users prefer to receive their calcium alloys in bags containing exactly 50 lbs. delivered in convenient-to-handle pallet crates holding approximately 1800 lbs.